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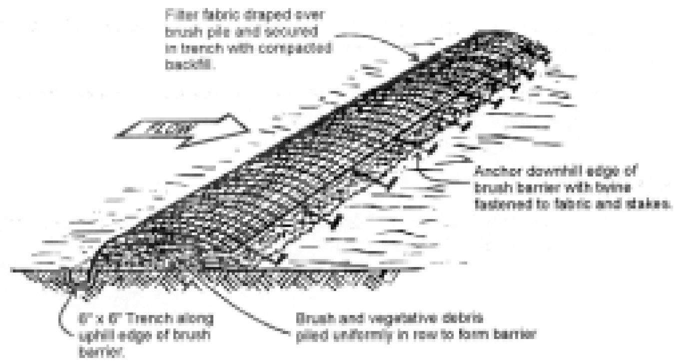
Practices

Brush Barrier

A temporary sediment barrier constructed at the perimeter of a disturbed area, using residue materials available from clearing and grubbing on-site.

Used to intercept and retain sediment from limited disturbed areas.



Where Practice Applies

Below disturbed areas of less than one quarter acre that are subject to sheet and rill erosion, where enough residue material is available for construction of such a barrier. Note: This does not replace a sediment trap or pond.

Advantages

- Brush barriers can often be constructed using materials found on-site.

Planning Considerations

Organic litter and spoil material from site clearing operations is usually hauled away to be disposed of elsewhere. Much of this material can be used effectively on the construction site itself. During clearing and grubbing operations, equipment can push or dump the mixture of limbs, small vegetation, and root mat along with minor amounts of soil and rock into windrows along the toe of a slope where erosion and accelerated runoff are expected.

Because brush barriers are fairly stable and composed of natural materials, maintenance requirements are small. Material containing large amounts of wood chips should not be used because of the potential for leaching from the chips.

Design Recommendations

Height - 3 feet maximum.

Width - 5 to 15 feet at base.

Filter fabric anchored over the berm will enhance its filtration capacity.

Practices

Preserving Natural Vegetation
Riprap
Rock Dam
Sand Dune & Sandblow Stabilization
Sand Fence
Sediment Basin
Sediment Fence
Sediment Trap
Seeding, permanent
Seeding, temporary
Silt Curtain
Slope Drain

Sodding
Staw or hay bale barrier
Stream Crossing
Streambank Protection & Stabilization
Subsurface Drain
Sump Pit
Surface Roughening
Topsoiling
Tree& Shrub Planting
Vegetated Swale
Water Bar
Waterway, grassed
Waterway, lined

Maintenance

Brush barriers generally require little maintenance. Heavy deposits of sediment may need removal. Occasionally, tearing of the filter fabric may occur.

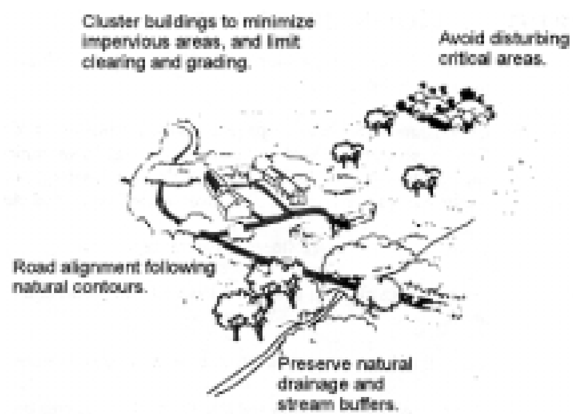
When the barrier is no longer needed the fabric can be removed to allow natural establishment of vegetation within the barrier. The barrier will rot over time.

References

Washington State Department of Ecology, ***Stormwater Management Manual for the Puget Sound Basin***, Olympia, WA, February, 1992.

Buffer Zones, Stream Corridors, and Riparian Areas

An undisturbed area or strip of natural vegetation or an established suitable planting that will provide a living filter to reduce soil erosion and runoff velocities.



Where Practice Applies

Natural buffer zones are used along streams and other bodies of water that need protection from erosion and sedimentation. Vegetative buffer zones can be used to protect natural swales and incorporated into natural landscaping of an area.

Advantages

Buffer zones provide critical habitat adjacent to streams and wetlands, as well as assist in controlling erosion, especially on unstable steep slopes. Buffers along streams and other water bodies also provide wildlife corridors, a protected area where wildlife can move from one place to another.

- Buffer zones act as a visibility and noise screen, and provide aesthetic benefits.
- Low maintenance requirements.
- Low cost when using existing vegetation.

Disadvantages/Problems

Extensive buffers will increase development costs.

Planning Considerations

- Preserving natural vegetation or plantings in clumps, blocks, or strips is generally the easiest and most successful method.
- Establishing new buffer strips requires the establishment of a good dense turf, trees, and shrubs. Careful maintenance is important to ensure healthy vegetation. The need for routine maintenance such as mowing, fertilizing, liming, irrigating, pruning, and weed and pest control will depend on the species of plants and trees involved, soil types, and climatic conditions.
- Leave all unstable steep slopes in natural vegetation.
- Fence or flag clearing limits and keep all equipment and construction debris out of the natural areas.
- Keep all excavations outside the dripline of trees and shrubs.
- Do not push debris or extra soil into the buffer zone area because it will cause damage from burying and smothering.

References

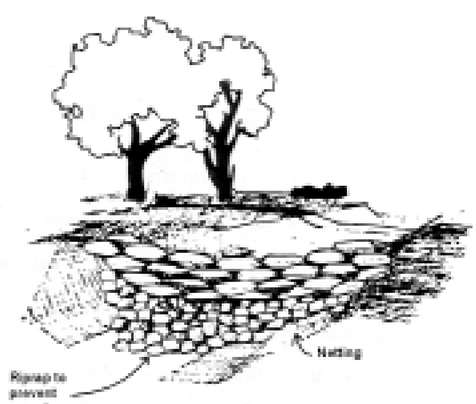
U. S. Environmental Protection Agency, ***Storm Water Management For Construction Activities,*** EPA-832-R- 92-005, Washington, DC, September, 1992.

Washington State Department of Ecology, ***Stormwater Management Manual for the Puget Sound Basin, Olympia***, WA, February, 1992.

Check Dam

A check dam is a small dam constructed across a drainage ditch, swale, or channel to lower the speed of flow. Reduced runoff speed reduces erosion and gullying in the channel and allows sediments to settle out.

A check dam may be built from stone, sandbags filled with pea gravel, or logs.



SANDBAG CHECK DAM

Purpose

To reduce flow velocity: reducing erosion of the swale or ditch, and allowing retention of sediments.

Where Practice Applies

Where temporary channels or permanent channels are not yet vegetated, channel lining is infeasible and velocity checks are required.

This practice may be used as a temporary or emergency measure to limit erosion by reducing flow in small open channels.

This practice should be used with drainage areas of 2 acres or less.

Check dams may be used:

- To reduce flow in small temporary channels that are presently undergoing degradation,
- Where permanent stabilization is impractical due to the temporary nature of the problem, and
- To reduce flow in small eroding channels where construction delays or weather conditions prevent timely installation of non-erosive liners.

Advantages

- Inexpensive and easy to install.
- Reduce velocity and may provide aeration of the water.
- Check dams not only prevent gully erosion from occurring before vegetation is established, but also cause a high proportion of the sediment load in runoff to settle out.
- In some cases, if carefully located and designed, these check dams can remain as permanent installations with very minor regrading, etc. They may be left as either spillways, in which case accumulated sediment would be graded and seeded, or as check dams to capture further sediment coming off that site.

Disadvantages/Problems

- Because of their temporary nature, many of these measures are unsightly, and they should be removed or converted to permanent check dams before dwelling units are rented or sold.
- Removal may be a significant cost depending on the type of check dam installed.
- Check dams are only suitable for a limited drainage area.
- May kill grass linings in channels if the water level remains high after rainstorms or if there is significant sedimentation.
- Reduce the hydraulic capacity of the channel.
- May create turbulence which erodes the channel banks.
- Clogging by leaves in the fall may be a problem.

Planning Considerations

Check dams are usually made of stone. The center section must be lower than the edges.

The dams should be spaced so that the toe of the upstream dam is at the same elevation as the top of the downstream dam.

Ensure that overflow areas along the channel are resistant to erosion from out-of-bank flow caused by the check dams.

Check dams can also be constructed of logs, or pea gravel filled sandbags. Log check dams may be more economical from the standpoint of material costs, since logs can often be salvaged from clearing operations. However, log check dams require more time and hand labor to install. Stone for check dams must generally be purchased. This cost is offset somewhat by the ease of installation.

If stone check dams are used in grass-lined channels which will be mowed, care should be taken to remove all the stone from the channel when the dam is removed. This should include any stone which has washed downstream.

Since log check dams are embedded in the soil, their removal will result in more disturbance of the soil than will removal of stone check dams. Consequently, extra care should be taken to stabilize the area when log dams are used in permanent ditches or swales.

Design & Construction Recommendations

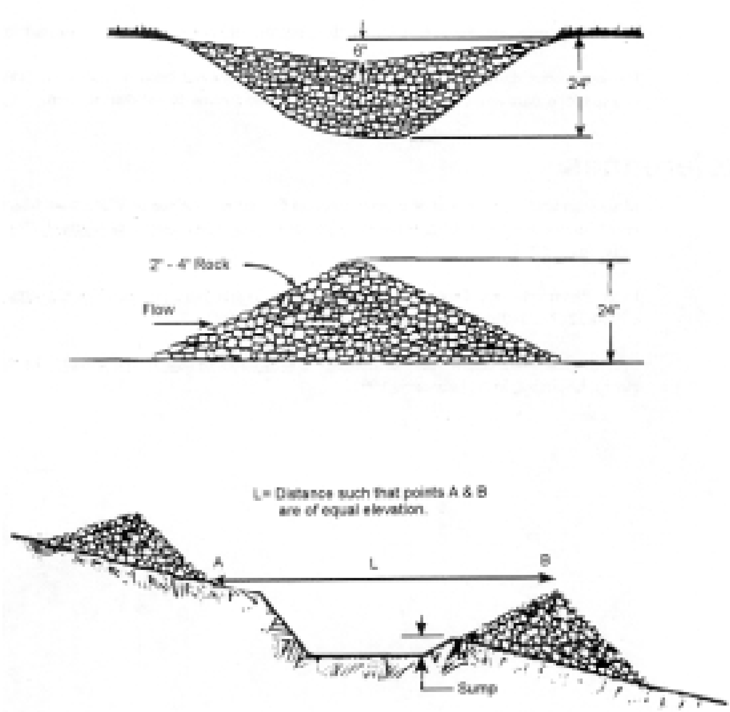
Check dams can be constructed of rock, sand bags filled with pea-gravel, or logs. Provide a sump immediately upstream.

The maximum spacing between the dams should be such that the toe of the upstream dam is at the same elevation as the top of the downstream dam.

The rock must be placed by hand or mechanical placement (do not dump rock to form dam) to achieve complete coverage of the ditch or swale and to ensure that the center of the dam is lower than the edges. The rock used must be large enough to stay in place given the expected design flow through the channel.

Log check dams should be constructed of 4 to 6-inch diameter logs embedded into the soil at least 18 inches.

In the case of grass-lined ditches and swales, check dams shall be removed when the grass has matured sufficiently to protect the ditch or swale unless the slope of the swale is greater than 4 percent. The area beneath the check dams shall be seeded and mulched immediately after dam removal.



Common Trouble Points

Stone displaced from face of dam
Stone size too small and/or face too steep.

Erosion downstream from dam
Provide stone-lined apron.

Erosion of abutments during high flow
Rock abutment height inadequate.

Sediment loss through dam
Inadequate layer of aggregate on inside face or aggregate too coarse to restrict flow through dam.

Maintenance

- Inspect after each rainfall event.
- Remove sediment accumulations.
- Check structure and abutments for erosion, piping, or rock displacement. Repair immediately.
- Remove check dam after the contributing drainage area has been permanently stabilized. Smooth site to blend with surrounding area and stabilize according to vegetation plan.

References

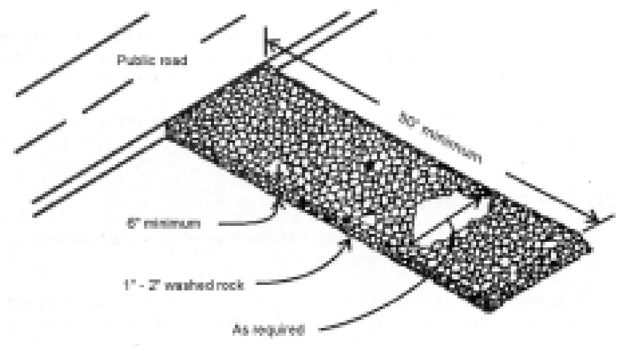
Massachusetts Department of Environmental Protection, Office of Watershed Management, Nonpoint Source Program, ***Massachusetts Nonpoint Source Management Manual***, Boston, Massachusetts, June, 1993.

U.S. Environmental Protection Agency, ***Storm Water Management For Construction Activities***, EPA-832-R-92-005, Washington, DC, September, 1992.

Washington State Department of Ecology, ***Stormwater Management Manual for the Puget Sound Basin***, Olympia, WA, February, 1992.

Construction Entrance

A temporary stone-stabilized pad located at points of vehicular ingress and egress on a construction site.



Purpose

To provide a stable entrance and exit from a construction site and keep mud and sediment off public roads.

Where Practice Applies

Whenever traffic will be leaving a construction site and moving directly onto a public road or other paved areas.

Advantages

- Mud on vehicle tires is significantly reduced which avoids hazards caused by depositing mud on the public roadway.
- Sediment, which is otherwise contained on the construction site, does not enter stormwater runoff elsewhere.

Disadvantages

Effective only if installed at every location where traffic leaves and enters the site.

Planning Considerations

Avoid locating at curves in public roads or on steep slopes.

Construction entrances provide an area where mud can be removed from vehicle tires before they enter a public road. If the action of the vehicle traveling over the gravel pad is not sufficient to remove the majority of the mud, then the tires must be washed before the vehicle enters a public road.

If washing is used, provisions must be made to intercept the wash water and trap the sediment before it is carried off-site. Construction entrances should be used in conjunction with the stabilization of construction roads to reduce the amount of mud picked up by vehicles.

This practice will only be effective if sediment control is used throughout the rest of the construction site.

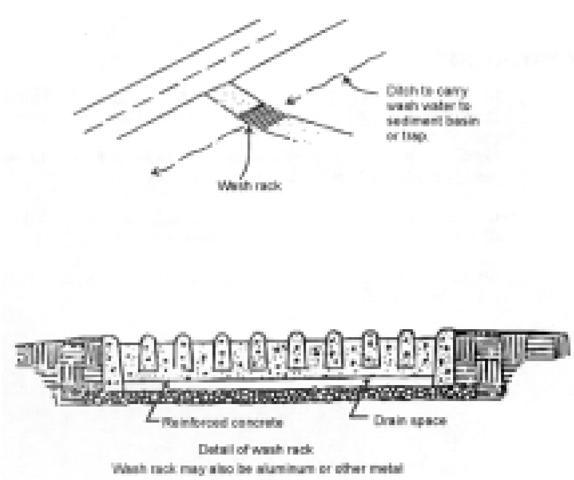
Design Recommendations

- Remove all vegetation and other objectionable material from the foundation area. Grade and crown foundation for positive drainage.
- Stone for a stabilized construction entrance shall be 1 to 3-inch stone, reclaimed stone, or recycled concrete equivalent placed on a stable foundation as specified in the plan.
- Pad dimensions: The minimum length of the gravel pad should be 50 feet, except for a single residential lot where a 30 foot minimum length may be used. Longer entrances will provide better cleaning action. The pad should extend the full width of the construction access road or 10 feet whichever is greater. The aggregate should be placed at least six inches thick.
- A geotextile filter fabric shall be placed between the stone fill and the earth surface below the pad to reduce the migration of soil particles from the underlying soil into the stone and vice versa. Filter cloth is not required for a single family residence lot.
- If the slope toward the road exceeds 2%, construct a ridge, 6 to 8 inches high with 3:1 side slopes, across the foundation approximately 15 ft from the entrance to divert runoff away from the public road.
- All surface water that is flowing to or diverted toward the construction entrance should be piped beneath the entrance. If piping is impractical, a berm with 5:1 slopes that can be crossed by vehicles may be substituted for the pipe.
- Washing: If the site conditions are such that the majority of mud is not removed from the vehicle tires by the gravel pad, then the tires should be washed before the vehicle enters the road or street. The wash area should be a level area with 3-inch washed stone minimum, or a commercial rack.
- Wash water should be directed into a sediment trap, a vegetated filter strip, or other approved sediment trapping device. Sediment should be prevented from entering any watercourses.
- A filter fabric fence should be installed down-gradient from the construction entrance in order to contain any sediment-laden runoff from the entrance.

Common Trouble Points

Inadequate runoff control
Sediment washes onto public road.

Stone too small, pad too thin, or geotextile fabric absent
Results in muddy condition as stone is pressed into soil.



Construction entrance with wash rack

Pad too short for heavy construction traffic
Extend pad beyond the minimum 50-ft length as necessary.
Pad not flared sufficiently at road entrance
Results in mud being tracked onto road and possible damage to road edge.
Unstable foundation
Use geotextile fabric under pad and/or improve foundation drainage.

Maintenance

- The entrance should be maintained in a condition that will prevent tracking or flowing of sediment onto public rights-of-way. This may require periodic topdressing with additional stone.
- Inspect entrance/exit pad and sediment disposal area weekly and after heavy rains or heavy use.
- Remove mud and sediment tracked or washed onto public road immediately.
- Mud and soil particles will eventually clog the voids in the gravel and the effectiveness of the gravel pad will not be satisfactory. When this occurs, the pad should be topdressed with new stone. Complete replacement of the pad may be necessary when the pad becomes completely clogged.
- If washing facilities are used, the sediment traps should be cleaned out as often as necessary to assure that adequate trapping efficiency and storage volume is available. Vegetative filter strips should be maintained to insure a vigorous stand of vegetation at all times.
- Reshape pad as needed for drainage and runoff control.
- Repair any broken road pavement immediately.
- All temporary erosion and sediment control measures shall be removed within 30 days after final site stabilization is achieved or after the temporary practices are no longer needed. Trapped sediment shall be removed or stabilized on site. Disturbed soil areas resulting from removal shall be permanently stabilized.

References

Minnick, E. L., and H. T. Marshall, ***Stormwater Management and Erosion Control for Urban and Developing Areas in New Hampshire***, Rockingham County Conservation District, August 1992.

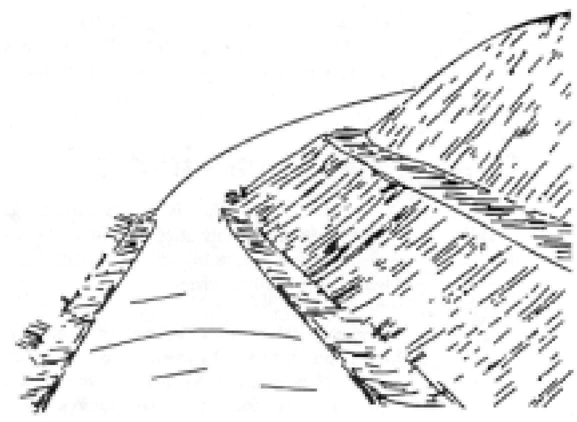
North Carolina Department of Environment, Health, and Natural Resources, ***Erosion and Sediment Control Field Manual***, Raleigh, NC, February 1991.

U.S. Environmental Protection Agency, ***Storm Water Management For Construction Activities*** EPA-832-R-92-005, Washington, DC, September, 1992.

Washington State Department of Ecology, ***Stormwater Management Manual for the Puget Sound Basin***, Olympia, WA, February, 1992.

Construction Road Stabilization

Stabilization of temporary construction access routes, on-site vehicle transportation routes, and construction parking areas to control erosion



Where Practice Applies

All traffic routes and parking areas for temporary use by construction traffic.

Advantages

- Proper grading and stabilization of construction roads and parking areas reduces erosion and prevents dust problems.
- Road stabilization can significantly speed on-site work, avoid instances of immobilized machinery and delivery vehicles, and generally improve site efficiency and working conditions during adverse weather.

Disadvantages/Problems

- Measures on temporary roads must be cheap not only to install but also to demolish if they interfere with the eventual surface treatment of the area.
- May require maintenance to replace aggregate or repair ruts.

Planning Considerations

- Avoid steep slopes, excessively wet areas, and highly erodible soils.
- Controlling surface runoff from the road surface and adjoining area is a key erosion control consideration. Provide surface drainage and divert excess runoff to stable areas.
- Areas which are graded for construction vehicle transport and parking purposes are especially susceptible to erosion. The exposed soil surface is continually disturbed, leaving no opportunity for vegetative stabilization. Such areas also tend to collect and transport runoff waters along their surfaces. During wet weather, they often become muddy quagmires which generate significant quantities of sediment that may pollute nearby streams or be transported off-site on the wheels of construction vehicles. Dirt roads can become so unstable during wet weather that they are virtually unusable.

- Immediate stabilization of such areas with stone may cost money at the outset, but it may actually save money in the long run by increasing the usefulness of the road during wet weather.
- Permanent roads and parking areas should be paved as soon as possible after grading. As an alternative, the early application of stone may solve potential erosion and stability problems and eliminate later regrading costs. Some of the stone will also probably remain in place for use as part of the final base course of the road.

Design Recommendations

- A 6-inch course of 2 to 4-inch crushed rock, gavel base, or crushed surfacing base course should be applied immediately after grading or the completion of utility installation within the right-of-way. A 4-inch course of asphalt-treated base may be used in lieu of the crushed rock, or as advised by the local government.
- Temporary roads should follow the contour of the natural terrain to the maximum extent possible. Slope should not exceed 15 percent. Roadways should be carefully graded to drain transversely. Provide drainage swales on each side of the roadway in the case of a crowned section, or one side in the case of a super-elevated section.
- Drain inlets should be protected to prevent sediment-laden water entering.
- Areas adjacent to culvert crossings and steep slopes should be seeded and mulched.
- Dust control should be used when necessary.

Maintenance

- Inspect stabilized areas regularly, especially after large storm events. Add crushed rock if necessary and restabilize any areas found to be eroding.
- All temporary erosion and sediment control measures should be removed within 30 days after final site stabilization is achieved or after the temporary practices are no longer needed.
- Trapped sediment should be removed or stabilized on site. Disturbed soil areas resulting from removal should be permanently stabilized.

References

Massachusetts Department of Environmental Protection, Office of Watershed Management, Nonpoint Source Program, Massachusetts ***Nonpoint Source Management Manual,*** Boston, Massachusetts, June, 1993.

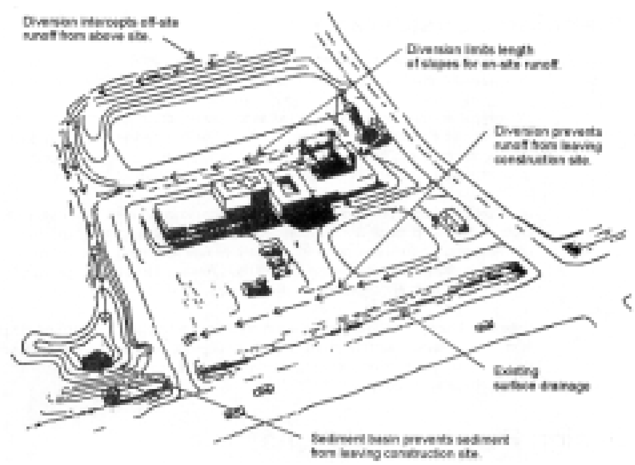
U.S. Environmental Protection Agency, ***Storm Water Management For Construction Activities*** EPA-832-R-92-005, Washington, DC, September, 1992.

Washington State Department of Ecology, ***Stormwater Management Manual for the Puget Sound Basin,*** Olympia, WA, February, 1992.

Diversion, Permanent

A permanent ridge or channel, or a combination ridge and channel, constructed: across sloping land; or at the top or bottom of a steep slope. Used to convey runoff water.

This practice is used to reduce slope lengths, break up concentration of runoff, and move water to stable outlets at a non-erosive velocity.



Where Practice Applies

This practice applies to sites where runoff can be diverted and used or disposed of safely to prevent flood damage or erosion and sediment damage, including:

- Above steep slopes to limit surface runoff onto the slope,
- Across long slopes to reduce slope length to prevent gully erosion,
- Below steep grades where flooding, seepage problems, or sediment deposition may occur,
- Around buildings or areas that are subject to damage from runoff.

Diversions must have stable outlets. The site, slopes, and soils must be such that the diversion can be maintained throughout its planned life.

Permanent diversions are not applicable below high sediment-producing areas unless land treatment practices, or structural measures, designed to prevent damaging accumulations of sediment in the channels, are installed with or before the diversions.

Advantages

Diversions are among the most effective and least costly practices for controlling erosion and sedimentation.

Planning Considerations

Permanent diversions should be planned as a part of initial site development. They are principally runoff control measures that subdivide the site into specific drainage areas.

Permanent diversions can be installed as temporary diversions until the site is stabilized then completed as a permanent measure, or they can be installed in final form during the initial construction operation. The amount of sediment anticipated and the maintenance required as a result of construction operations will determine which approach should be used.

Stabilize permanent diversions with vegetation or materials such as riprap, paving stone, or concrete as soon as possible after installation. Base the location, type of stabilization, and diversion configuration on final site conditions. Evaluate function, need, velocity control, outlet stability, and site aesthetics. When properly located, land forms such as landscape islands, swales or ridges can be used effectively as permanent diversions.

Base the capacity of a diversion on the runoff characteristics of the site and the potential damage after development. Consider designing an emergency overflow section or bypass area to limit damage from storms that exceed the design storm. The overflow section may be designed as a weir with riprap protection.

Design Recommendations

Capacity

Peak runoff values should be determined by accepted methods. Recommended minimum design frequencies are shown below. In all cases, the design storm frequency should be chosen to provide protection compatible with the hazard or damage that would occur if the diversion should overtop.

Homes, schools, industrial buildings, etc.	**50-year design frequency**
Playfields, recreation areas, similar land areas	**25-year design frequency**

Permissible Flow Velocity

Soil Texture	Bare Channel	Vegetated Channel
Sand, silty sandy loam	1.5 feet/second	2.5 feet/second
Silty clay and sandy clay loam	2.0 feet/second	3.5 feet/second
Clay	2.5 feet/second	4.5 feet/second

Cross Section

The channel may be parabolic or trapezoidal. It should be designed to have stable side slopes.

Side slopes for permanent diversions should not be steeper than 3:1 for maintenance purposes and preferably 4:1. In no case should side slopes be steeper than 1:1.

Back slope of the ridge is not to be steeper than 2:1 and preferably 4:1.

The **ridge** should include a settlement factor equal to 5 percent of its height.

The minimum **top width** of the diversion ridge after settlement is to be 4.0 feet at the design elevation.

Freeboard equalling 0.5 foot minimum.

In determining the cross section on temporary diversions, consideration should be given to soil type and frequency and type of equipment that is anticipated to be crossing the diversion.

Grade

Channel grade for diversions may be uniform or variable. The permissible velocity for the soil type and vegetative cover will determine maximum grade. Level diversions with blocked ends may be used, provided pipes of sufficient size and spacing are placed in the embankment to drain the channel after runoff stops.

Outlets

Diversions are to have adequate outlets which will convey runoff without damaging erosion. The following types of outlets are acceptable:

Natural or constructed vegetated outlets capable of safely carrying the design discharge. The outlet should be established and well vegetated prior to construction of the diversion.

Properly designed and constructed **grade stabilization structures** or **storm sewers.**

Natural or constructed open channels which are stable and have adequate capacity and depth.

A **stable area** having a good sod cover or a woodland area with a deep erosion resistant litter. The outlet end of the diversion channel should be flared in a manner to spread the water over a wide area at a shallow depth.

Level Spreader

A level lip spreader should be used at diversion outlets discharging onto area already stabilized by vegetation. Spreaders shall be excavated at least 6 inches deep into undisturbed soil. The bottom of the excavation and the downstream lip of edge shall be level. Minimum spreader lengths shall be based on the peak rate of flow from a 10-year frequency storm.

Diversion Dikes

Diversion dikes should be used to divert runoff for temporary or permanent protection of cut or fill slopes. Diverted runoff must be discharged onto a stabilized area or through a slope-protection structure.

Recommended criteria:

- **Drainage area** - 5 acres or less.
- **Top width** - 2 feet minimum.
- **Height** (compacted fill) - 18 inches unless otherwise noted on the plans. (Height measured from the upslope toe to top of the dike.)
- **Side slopes** - 2:1 or flatter.
- **Grade** - dependent upon topography, but must have positive drainage to the outlet; may require vegetative or mechanical stabilization where grades are excessive.

Protection Against Sediment

Temporary diversions - None required.

Permanent diversions - As a minimum, a filter strip of close growing grass should be maintained above the channel. The width of the filter, measured from the center of the channel, should be one-half the channel width plus 15 feet.

The diversion ridge and channel should be vegetated to prevent erosion.

Small eroded areas and sediment-producing channels draining into the diversion should be shaped and seeded prior to or at the time the diversion is constructed.

Construction Recommendations

All trees, brush, stumps, and other objectionable material should be removed so they will not interfere with construction or proper functioning of the diversion.

All ditches or gullies which must be crossed should be filled and compacted prior to or as part of the construction.

Fence rows and other obstructions that will interfere with construction or the successful operation of the diversion should be removed.

The base for the diversion ridge should be prepared so that a good bond is obtained between the original ground and the placed fill. Vegetation should be removed and the base thoroughly disked before placement of the fill.

Vegetation

Diversions should be vegetated as soon after construction as practical. Give consideration to jute matting, excelsior matting, or sodding of channel to provide erosion protection.

Seeding, fertilizing, mulching, and sodding should be in accord with applicable vegetative standards for permanent cover. See Permanent Seeding.

One-half to one bushel of oats should be added to the basic mixture for quick cover and to help anchor the mulch.

Very moist channels are often best vegetated by working rootstocks of reed canarygrass into the seedbed.

When soil conditions are unfavorable for vegetation (such as very coarse-textured subsoil material), topsoil should be spread to a depth of 4 inches or more on at least the center half of parabolic shaped channels or on the entire bottom of trapezoidal shaped channels.

Seeded channels should be mulched. For critical sections of large channels, and for steep channels, the mulch should be anchored by cutting it lightly into the soil surface, or by covering with paper twine fabric or equivalent material; or jute netting should be used.

Maintenance

If no sediment protection is provided on temporary diversions, periodic cleanout will probably be required.

References

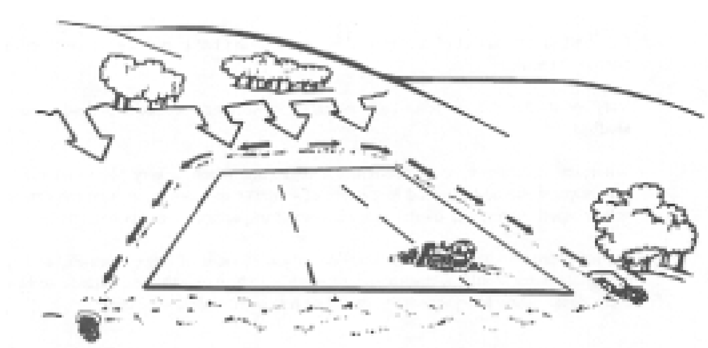
Massachusetts Department of Environmental Protection, Office of Watershed Management, Nonpoint Source Program, Massachusetts ***Nonpoint Source Management Manual,*** Boston, Massachusetts, June, 1993.

North Carolina Department of Environment, Health, and Natural Resources, ***Erosion and Sediment Control Field Manual***, Raleigh, NC, February 1991.

North Carolina Sediment Control Commission, ***Erosion and Sediment Control Planning and Design Manual***, Raleigh, NC, September, 1988.

Diversion,Temporary

A permanent ridge or channel, or a combination ridge and channel, constructed: across sloping land; or at the top or bottom of a steep slope. Used to convey runoff water.



Purpose

- To reduce slope lengths, break up concentration of runoff, and move water to stable outlets at a non-erosive velocity.
- To protect work areas from upslope runoff.
- To divert sediment-laden water to an appropriate sediment-trapping facility.

Where Practice Applies

This practice applies to construction areas where runoff can be diverted and disposed of properly to control erosion, sedimentation, or flood damage. Specific locations and conditions include:

- Above disturbed existing slopes, and above cut or fill slopes to prevent runoff over the slope;

- Across unprotected slopes, as slope breaks, to reduce slope length;
- Below slopes to divert excess runoff to stabilized outlets;
- Where needed to divert sediment-laden water to sediment traps;
- At or near the perimeter of the construction area to keep sediment from leaving the site;
- Above disturbed areas before stabilization to prevent erosion and maintain acceptable working conditions.
- Where active construction activities make the use of a permanent diversion unfeasible.

Temporary diversions may also serve as sediment traps when the site has been overexcavated on a flat grade. They may also be used in conjunction with a sediment fence.

Advantages

Diversions are among the most effective and least costly practices for controlling erosion and sedimentation.

Planning Considerations

A temporary diversion is intended to divert overland sheet flow to a stabilized outlet or a sediment trapping facility during establishment of permanent stabilization on a sloping disturbed area. When used at the top of a slope, the structure protects exposed slopes by keeping upland runoff away. When used at the base of a slope, the structure protects adjacent and downstream areas by diverting sediment-laden runoff to a sediment trapping facility.

If the diversion is going to remain in place for longer than 15 days, it should be stabilized with temporary or permanent vegetation.

It is important that diversions are properly designed, constructed and maintained since they concentrate water flow and increase erosion potential. Particular care must be taken in planning diversion grades. Too much slope can result in erosion in the diversion channel or at the outlet. A change of slope from steeper grade to flatter may cause deposition to occur. The deposition reduces carrying capacity and may cause overtopping and failure.

Frequent inspection and timely maintenance are essential to proper functioning.

Sufficient area must be available to construct and properly maintain diversions. It is usually less costly to excavate a channel and form a ridge or dike on the downhill side with the spoil than to build diversions by other methods. Where space is limited, it may be necessary to build the ridge by hauling in dike fill material or using a sediment fence to divert the flow. Use gravel to form the diversion dike where vehicles must cross frequently.

Temporary diversions may be planned to function one year or more, or they may be constructed anew at the end of each days grading operation to protect new fill.

Temporary diversions may serve as in-place sediment traps if overexcavated 1 to 2 feet and placed on a nearly flat grade. The dike serves to divert water as the stage increases. A combination silt fence and channel in which fill from the channel is used to stabilize the fence can trap sediment and divert runoff simultaneously.

Wherever feasible, build and stabilize diversions and outlets before initiating other landdisturbing activities.

Design Criteria

Temporary diversions must be planned to be stable throughout their useful life and meet criteria given below. Otherwise, they should be designed as permanent diversions.

Drainage area
Not more than three acres.

Capacity
Peak runoff from 10-year storm.

Minimum cross section:

Top Width	Height	Side Slopes
0 ft.	1.5 ft.	4:1
4 ft	1.5 ft.	2:1

Grade

The grade may be variable depending upon the topography and must have a positive grade to the outlet. The maximum channel grade should be limited to 1.0 percent.

Spacing
The maximum spacing of diversions on side slopes or graded rights-of-way should be no greater than the following:

Land Slope (%)	Spacing (ft.)
1 or less	300
2	200
3-5	150
5 or greater	100

Diverted runoff should outlet onto a stabilized area, into a properly designed waterway, grade stabilization structure or sediment trapping facility.

Diversions that are to serve longer than 30 working days should be seeded and mulched as soon as they are constructed, in order to preserve dike height and reduce maintenance.

Maintenance

Inspect temporary diversions once a week and after every rainfall.

Damage caused by construction traffic or other activity should be repaired before the end of each working day.

Immediately remove sediment from the flow area and repair the diversion ridge.

Check outlets carefully and make timely repairs as needed.

When the area protected has been permanently stabilized, remove the ridge and the channel to blend with the natural ground level, and appropriately stabilize it.

References

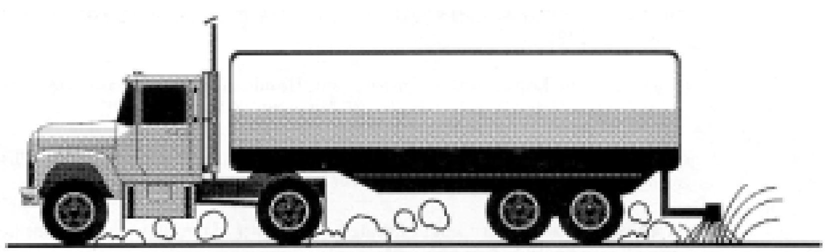
Massachusetts Department of Environmental Protection, Office of Watershed Management, Nonpoint Source Program, ***Massachusetts Nonpoint Source Management Manual***, Boston, Massachusetts, June, 1993.

North Carolina Department of Environment, Health, and Natural Resources, ***Erosion and Sediment Control Field Manual***, Raleigh, NC, February 1991.

North Carolina Sediment Control Commission, ***Erosion and Sediment Control Planning and Design Manual***, Raleigh, NC, September, 1988.

Washington State Department of Ecology, ***Stormwater Management Manual for the Puget Sound Basin***, Olympia, WA, February, 1992.

Dust Control



Reducing surface and air movement of dust from exposed soil surfaces during land disturbing, demolition, and construction activities.

Where Practice Applies

On construction routes and other disturbed areas subject to surface dust movement and dust blowing where on-site and off-site damage is likely to occur if preventive measures are not taken.

Advantages

A decrease in the amount of dust in the air will decrease the potential for accidents and respiratory problems.

Disadvantages/Problems

Excessive use of water to control dust emissions, particularly in areas where the soil has been compacted, can cause a runoff problem.

Planning Considerations

Large quantities of dust can be generated during land grading activities for commercial, industrial, or subdivision development, especially during dry, windy weather. Research at construction sites has established an average dust emission rate of 1.2 tons/acre/month for active construction. Earthmoving activities comprise the major source of construction dust emissions, but traffic and general disturbance of the soil also generate significant dust emissions.

In planning for dust control, it is important to schedule construction activities so that the least area of disturbed soil is exposed at one time.

For disturbed areas not subject to traffic, vegetation provides the most practical and efficient means of dust control. For other areas control measures include mulching, sprinkling, spraying adhesive or calcium chloride, and wind barriers.

Maintain dust control measures properly through dry weather periods until all disturbed areas have been permanently stabilized.

Methods

Vegetative Cover - For disturbed areas not subject to traffic, vegetation provides the most practical method of dust control.

Mulch (including Gravel Mulch) - When properly applied, mulch offers a fast, effective means of controlling dust.

Spray-on Adhesive - Latex emulsions or resin in water can be sprayed onto mineral soil to prevent particles from blowing away.

Calcium Chloride - Calcium chloride may be applied by mechanical spreader as loose, dry granules or flakes at a rate that keeps the surface moist but not so high as to cause water pollution or plant damage.

Sprinkling - The site may be sprinkled until the surface is wet. Sprinkling is especially effective for dust control on haul roads and other traffic routes.

Stone - Used to stabilize construction roads; can also be effective for dust control.

Barriers - A board fence, wind fence, sediment fence, or similar barrier can control air currents and blowing soil. All of these fences are normally constructed of wood and they prevent erosion by obstructing the wind near the ground and preventing the soil from blowing offsite.

A wind barrier generally protects soil downward for a distance of 10 times the height of the barrier. Perennial grass and stands of existing trees may also serve as wind barriers.

Maintenance

Respray area as necessary to keep dust to a minimum.

References

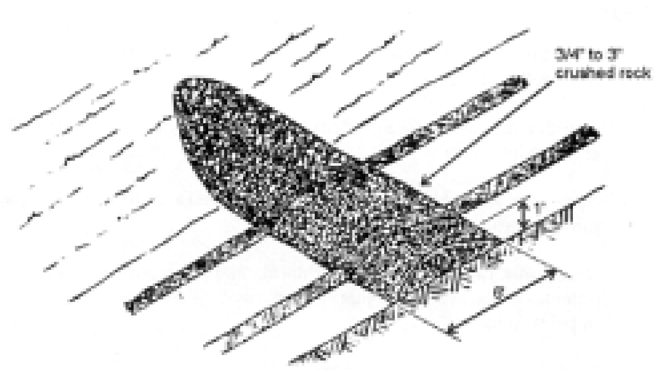
Massachusetts Department of Environmental Protection, Office of Watershed Management, Nonpoint Source Program, Massachusetts ***Nonpoint Source Management Manual,*** Boston, Massachusetts, June, 1993.

U.S. Environmental Protection Agency, ***Storm Water Management For Construction Activities***, EPA-832-R- 92-005, Washington, DC, September, 1992.

Washington State Department of Ecology, ***Stormwater Management Manual for the Puget Sound Basin***, Olympia, WA, February, 1992.

Filter Berm

A filter berm is a temporary ridge constructed of loose gravel, stone, or crushed rock. It slows and filters flow, diverting it from an exposed traffic area. It is used to retain sediment from traffic areas.



Where Practice Applies

Where a temporary measure is needed to retain sediment from rights-of-way or in traffic areas on construction sites.

Advantages

This is an efficient method of sediment removal.
Reduces the speed of runoff flow.

Disadvantages/Problems

- A gravel filter berm is more expensive to install than other practices which use materials found on-site.
- Has a limited life span.
- Can be difficult to maintain because of clogging from mud and soil on vehicle tires.

Design Criteria

Berm material should be ¾ to 3 inches in size, washed, well-graded gravel or crushed rock with less than 5 percent fines.

Spacing of berms:

- Every 300 feet on slopes less than 5 percent.
- Every 200 feet on slopes between 5 and 10 percent.
- Every 100 feet on slopes greater than 10 percent.

Berm dimensions:

- 1 foot high with 3:1 side slopes.
- 8 linear feet per 1 cfs runoff based on the 10-year, 24-hour design storm.

Maintenance

Filter berms should be inspected regularly after each rainfall, or if damaged by construction traffic. All needed repairs should be performed immediately.

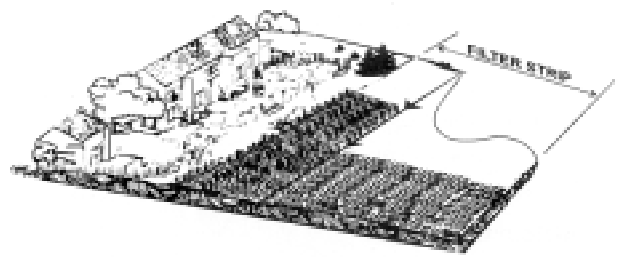
Accumulated sediment should be removed and properly disposed of and the filter material replaced, as necessary.

References

U.S. Environmental Protection Agency, ***Storm Water Management For Construction Activities***, EPA-832-R-92-005, Washington, DC, September, 1992.

Washington State Department of Ecology, ***Stormwater Management Manual for the Puget Sound Basin***, Olympia, WA, February, 1992.

Filter Strip, Vegetated



A vegetated filter strip is an area of vegetation for runoff to flow through before it leaves a disturbed site or enters into a designed drainage system. It improves water quality by removing sediment and other pollutants from runoff as it flows through the filter strip. Some of the sediment and pollutants are removed by filtering, absorption, adsorption and settling as the velocity of flow is reduced.

Where Practice Applies

This practice applies to any site where adequate vegetation can be established and maintained. Vegetative filter strips can be used effectively:

- Surrounding stormwater management infiltration practices to reduce the sediment load delivered to the structures;
- Adjacent to water courses such as waterways and diversions and water bodies such as streams, ponds, and lakes;
- At the outlets of stormwater management structures; or
- Along the top of and at the base of slopes.

A vegetative filter strip is designed to provide runoff treatment of conventional pollutants but not nutrients. This practice is not designed to provide streambank erosion control. A vegetative filter strip should not be used for conveyance of larger storms because of the need to maintain sheet flow conditions. Also, the filter strip would likely be prohibitively large for this application.

Planning Considerations

Filter strips may occur naturally or be constructed. It is important that filter strips be designed and constructed so that runoff flows uniformly across the filter strip as sheet flow. Once the flow becomes concentrated in rills, the effectiveness of the strip is greatly reduced. It is essential that some type of device such as a level spreader or shallow stone trench be used to distribute the runoff evenly across the strip.

Natural filter areas can provide excellent pollutant removal, particularly those areas left adjacent to natural water courses and bodies of water. It is also important to evenly distribute the runoff into these natural areas for best performance. These natural areas can provide excellent wildlife habitat and travel corridors.

To prevent soil compaction, no equipment should be allowed to operate within the filter strip area. Uncompacted soil encourages percolation and minimizes rapid surface runoff.

Design Recommendations

Drainage Area

Maximum recommended drainage area is 5 acres.

Entrance Conditions

Runoff must be introduced to the filter strip as uniform sheet flow. A level spreader can be used to distribute the runoff onto the filter strip by constructing the lip of the spreader and the top of the strip at the same elevation or contour. In some cases, a shallow stone trench can be used to intercept the runoff and allow the water to outlet evenly as long as the lower edge of the stone trench is constructed level. Make provisions to avoid flow bypassing the filter strip.

Length

Filter strip length (parallel to flow) should be designed to produce a water residence time of at least 20 minutes (the length should normally be in the range of 100-200 feet).
Vegetative filter strips should not receive concentrated flow discharges as their effectiveness will be destroyed plus the potential for erosion could cause filter strips to become sources of pollution.

Slope

Vegetative filter strips should not be used on slopes greater than about 15 percent because of the difficulty in maintaining the necessary sheet flow conditions.

Width of Strip

The minimum width of a filter strip should be 20 feet for slopes up to 1%. An additional 4 feet for each 1% of slope should be added. Experience has found that strips from 50 to 75 feet wide perform best.

Vegetation

A dense stand of vegetation is necessary for a well functioning filter strip. A temporary diversion should be used to divert runoff away from the filter strip until good vegetation is established; otherwise rills will develop and reduce the effectiveness of the strip.

Maintenance

Filter strips should be maintained as natural areas once the vegetation is established. The filter strip should be protected from damage by fire, grazing, traffic, and dense weed growth.

Fertilization needs should be determined by on-site inspections. Supplemental fertilizer is a key factor, as most species take two to three years to become fully established.

The filter strip should be inspected periodically and after every major rainstorm to determine if the entrance conditions are still uniform and level and to see if rills have formed. Any problem areas should be repaired promptly to prevent further deterioration.

References

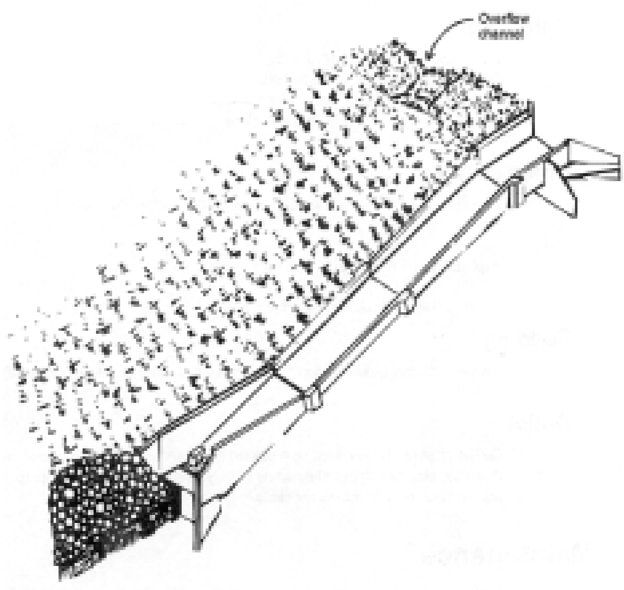
Minnick, E. L., and H. T. Marshall, ***Stormwater Management and Erosion Control for Urban and Developing Areas in New Hampshire,*** Rockingham County Conservation District, August 1992.

Massachusetts Department of Environmental Protection, Office of Watershed Management, Nonpoint Source Program, ***Massachusetts Nonpoint Source Management Manual,*** Boston, Massachusetts, June, 1993.

Washington State Department of Ecology, ***Stormwater Management Manual for the Puget Sound Basin***, Olympia, WA, February, 1992.

Flume, Paved

A paved flume is a permanent lined channel constructed on a slope. Paved flumes are used routinely on parking lot fills and highway cuts and fills to take runoff down the slope without causing erosion. The flumes may be constructed of concrete, asphalt, or masonry. The outlet of the flume should be protected to avoid erosion.



Where Practice Applies

This is a permanent practice that applies where stormwater runoff must be conveyed from the top of a cut or fill slope to the bottom.

Design Recommendations

This practice should be designed by a professional engineer.

Capacity
Paved flumes should be designed to pass the peak rate of flow expected from a 10 year frequency storm unless local regulations require a lower frequency higher discharge storm event.

Slope
The steepest slope of the structure shall be 1.5 horizontal to 1 vertical (1.5:1) where the flume is located in natural ground. The maximum slope shall be 2 horizontal to 1 vertical (2:1) on fill slopes.

Cutoff Walls
Cutoff walls shall be provided at the beginning and end of the flume. The wall should extend the full width of the flume and a minimum of 18 inches into the soil below the bottom of the flume. Cutoff wall should be at least 6 inches thick. Concrete walls should be reinforced with #4 bars spaced on 6 inch centers in both directions.

Cross section
Concrete flume walls will need to be at least 4 inches thick and reinforced with welded wire fabric.
Asphalt lined flumes should be at least 3 inches thick.
Masonry flumes should be a minimum of 4 inches thick.

Bedding
All paved flumes should be constructed on a 6 inch layer of sand-gravel bedding material.

Outlet
Outlets of paved flumes must be protected from erosion with some type of energy dissipater. The dissipater may be a designed structure or may be constructed of rock riprap capable of withstanding the velocity of flow from the chute.

Maintenance

Little maintenance is required for a paved flume, but the flume should be inspected periodically to see if cracks have developed in the lining. Any cracks should be repaired immediately. The energy dissipater should be checked to see that it is functioning properly. Any erosion below the dissipater should be repaired immediately.

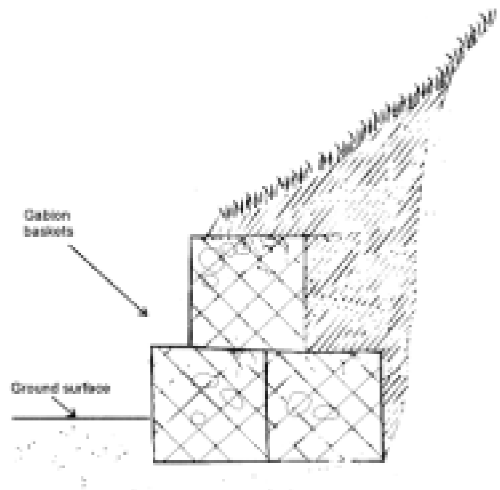
References

Minnick, E. L., and H. T. Marshall, ***Stormwater Management and Erosion Control for Urban and Developing Areas in New Hampshire,*** Rockingham County Conservation District, August 1992.

Massachusetts Department of Environmental Protection, Office of Watershed Management, Nonpoint Source Program, ***Massachusetts Nonpoint Source Management Manual, Boston***, Massachusetts, June, 1993.

Gabions

Gabions are rectangular baskets fabricated from a hexagonal mesh of heavily galvanized steel wire. The baskets are filled with stone and rock and stacked atop one another to form a gravity-type wall. Gabions depend mainly on the interlocking of the individual stones and rocks within the wire mesh for internal stability, and their mass or weight to resist hydraulic and earth forces. Gabions are a porous type of structure that can be vegetated.



Purpose

To slow the velocity of concentrated runoff or to stabilize slopes with seepage problems and/or noncohesive soils.

Where Practice Applies

Soil-water interfaces, where the soil conditions, water turbulence, water velocity, and expected vegetative cover, are such that the soil may erode under the design flow conditions. Gabions can be used on steeper slopes than riprap.

Advantages

Some advantages of gabion walls are:

- Ease of handling and transportation
- Speed of construction
- Flexibility (Gabions tolerate movement)
- Permeability to water (Good drainage)

Gabions offers an easy-to-use method for decreasing water velocity and protecting slopes from erosion.

Disadvantages/Problems

Gabions are sometimes criticized as being unsightly. They can be made more attractive by use of attractive facing stone toward the front of the wall and by establishing vegetation in the spaces between the rocks.

Gabions are more expensive than either vegetated slopes or riprap.

The wire baskets used for gabions may be subject to heavy wear-and-tear due to wire abrasion by bedload movement in streams with high velocity flow.

Planning Considerations

For easy handling and shipping, gabions are supplied folded into a flat position and bundled together. Gabions are readily assembled by unfolding and binding together all vertical edges with lengths of connecting wire stitched around the vertical edges. The empty gabions are placed in position and wired to adjoining gabions. They are then filled with cobblestone-size rock (10-30 cm in diameter) to one-third their depth. Connecting wires, placed in each direction, brace opposing gabion walls together. The wires prevent the gabion baskets from “bulging” as they are filled. This operation is repeated until the gabion is filled. After filling, the top is folded shut and wired to the ends, sides, and diaphragms.

During the filling operation live rooting plant species, such as willow, may be placed among the rocks. If this is done, some soil should be placed in the gabions with the branches, and the basal ends of the plants should extend well into the backfill area behind the gabion breast wall.

Several different design configurations are possible with gabions. They may have either a battered (sloping) or a stepped-back front. The choice depends upon application, although the stepped-back type is generally easier to build when the wall is more than 10 ft high.

If large rocks are readily accessible, inexpensive, and near the proposed site, then their use in construction of a rock wall may be preferable. On the other hand, if rock must be imported or is only available in small sizes, a gabion wall may be preferable.

Sequence of Construction

Since gabions are used where erosion potential is high, construction must be sequenced so that they are put in place with the minimum possible delay. Disturbance of areas where gabions are to be placed should be undertaken only when final preparation and placement can follow immediately behind the initial disturbance.

Where gabions are used for outlet protection, they should be placed before or in conjunction with the construction of the pipe or channel so that they are in place when the pipe or channel begins to operate.

Maintenance

Gabions should be inspected on a regular basis and after every large storm event.

All temporary and permanent erosion and sediment control practices shall be maintained and repaired as needed to assure continued performance of their intended function. All maintenance and repair shall be conducted in accordance with an approved manual.

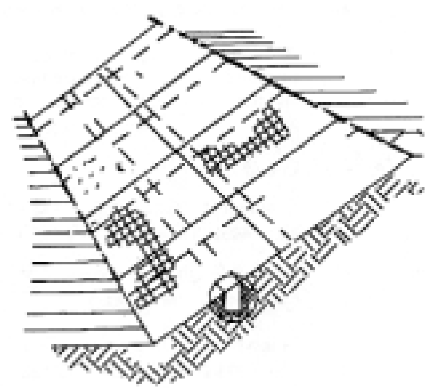
References

Connecticut Council on Soil and Water Conservation, ***Connecticut Guidelines for Soil Erosion and Sediment Control***, Hartford, CT, January, 1985.

Gray, Donald H. and Leiser, A. T., ***Biotechnical Slope Protection and Erosion Control***, Leiser Van Reinhold Inc., 1982.

Pennsylvania, Commonwealth of, Bureau of Soil and Water Conservation, ***Erosion and Sediment Pollution Control Program Manual***, Harrisburg, PA, April, 1990.

Geotextiles



Geotextiles are porous fabrics known in the construction industry as filter fabrics, road rugs, synthetic fabrics, construction fabrics, or simply fabrics. Geotextiles are manufactured by weaving or bonding fibers made from synthetic materials such as polypropelene, polyester, polyethylene, nylon, polyvinyl chloride, glass and various mixtures of these.

Some geotextiles are also biodegradable materials such as mulch matting and netting. Mulch mattings are materials (jute or other wood fibers) that have been formed into sheets of mulch that are more stable than normal mulch. Netting is typically made from jute, other wood fiber, plastic, paper, or cotton and can be used to hold the mulching and matting to the ground.

Purpose

As a synthetic construction material, geotextiles are used for a variety of purposes in the United States and other countries. The uses of geotextiles include separators, reinforcement, filtration and drainage, and erosion control. Netting can also be used alone to stabilize soils while the plants are growing; however, it does not retain moisture or temperature well.

Where Practice Applies

Geotextiles, when used alone, can be used as matting. Mattings are used to stabilize the flow in channels and swales. Matting may also be used on recently planted slopes to protect seedlings until they become established and on tidal or stream banks where moving water is likely to wash out new plantings.

Geotextiles are also used as separators. An example of such a use is geotextile as a separator between riprap and soil. This ‘sandwiching’ prevents the soil from being eroded from beneath the riprap and maintaining the riprap’s base.

Advantages

- Fabrics are relatively inexpensive for certain applications.
- A wide variety of geotextiles to match specific needs is available.

Disadvantages/Problems

If the fabric is not property selected, designed, or installed, the effectiveness may be reduced drastically.

Many synthetic geotextiles are sensitive to light and must be protected prior to installation.

Planning Considerations

There are numerous types of geotextiles available, therefore the selected fabric should match its purpose. In the field, important concerns include regular inspections to check for cracks, tears, or breaches in the fabric.

Effective netting and matting require firm, continuous contact between the materials and the soil. If there is no contact, the material will not hold the soil and erosion will occur underneath the material.

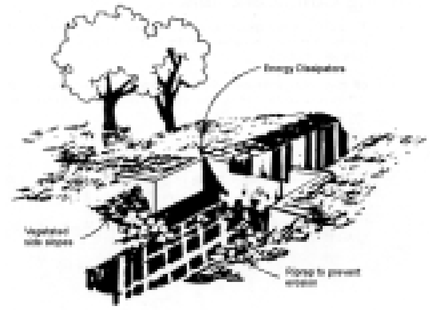
References

“Installing Erosion Control Blankets,” ***Erosion Control, The Journal For Erosion & Sediment Control Professionals***, Vol. 1, No. 4, September/ October 1994.

U.S. Environmental Protection Agency, ***Storm Water Management For Construction Activities***, EPA-832-R- 92-005, Washington, DC, September, 1992.

Grade Stabilization Structure

A permanent structure used to drop water from a higher elevation to a lower elevation. Grade stabilization structures are used to reduce or prevent excessive erosion by reducing velocities in a watercourse or by providing channel linings or structures that can withstand high velocities.



Where Practice Applies

This practice applies to sites where earth and vegetation cannot safely handle water at permissible velocities, where excessive grades or overfall conditions are encountered, or where water is to be structurally lowered from one elevation to another. These structures should be planned and installed along with or as a part of other conservation practices in an overall surface water disposal system.

Planning Considerations

Permanent grade stabilization structures may be constructed of concrete, metal, rock riprap, timber, or other suitable material. The choice of material is dependent on the proposed life of the structure, availability of materials, site specification, and soil conditions where the structure will be installed.

Generally, concrete structures are more expensive and more complicated to build, however they are more durable. Prefabricated metal structures are available at a slightly lower cost and are not as complicated to install. Rock riprap is a less expensive alternative where an adequate supply of durable rock is available, but will require more maintenance. Timber structures are not as easily installed as rock riprap, nor are they as durable.

Permanent grade stabilization structures are dependent on adequate tailwater conditions for proper functioning. Without adequate tailwater, erosion at the toe of the structure will eventually cause failure.

Design Recommendations

Design and specifications should be prepared for each structure on an individual job basis by a qualified engineer.

Overfall structures of concrete, metal, rock riprap, or other suitable material may be used to lower water from one elevation to another. These structures are applicable where it is desirable to drop the watercourse elevation over a very short horizontal distance. Adequate protection should be provided to prevent erosion or scour problems at both the upstream and downstream ends of the structure as well as along sides of the structure.

Pipe drops of metal pipe may be used with suitable inlet and outlet structures. The inlet structure may consist of a vertical section of pipe, an embankment, or a combination of both. The outlet structure shall provide adequate protection against erosion or scour at the pipe outlet.

Capacity

Structures which are designed to operate in conjunction with other erosion control practices should have as a minimum sufficient capacity to handle the bankfull capacity of the channel delivering water to the structure.

The minimum design capacity for grade control structures that are not designed to perform in conjunction with other practices should be that required to handle a 25-year frequency 24-hour duration storm.

Runoff values should be computed using accepted methods.

Maintenance

Grade stabilization structures should be checked at least annually and after every major storm. Concrete structures should be checked for concrete deterioration, settlement, and joint integrity. Pipe structures should be checked for deterioration of the pipe, settlement, and joint integrity. The outlets of the structures should be checked to see if the outlet is stable and is not eroding. If repairs are necessary, they should be made immediately to avoid further damage to the structures.

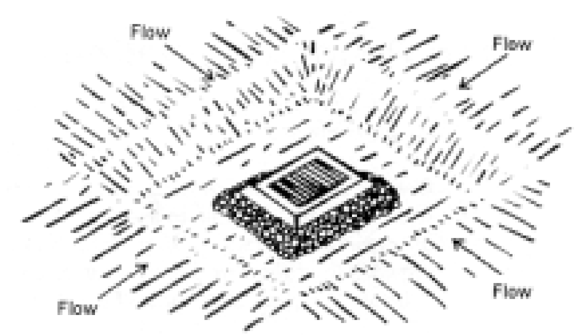
References

Minnick, E. L., and H. T. Marshall, ***Stormwater Management and Erosion Control for Urban and Developing Areas in New Hampshire***, Rockingham County Conservation District, August 1992.

Inlet Protection

A sediment filter or an excavated impounding area around a storm drain, drop inlet, or curb inlet.

Used to prevent sediment from entering storm drainage systems prior to permanent stabilization of the disturbed area. This practice allows for early use of the drainage system.



Where Practice Applies

Where storm drains are to be made operational before permanent stabilization of the disturbed drainage area.

Inlet protection is a temporary measure used where the drainage area to the inlet or inlets of a storm drain system is disturbed and it is not possible to divert sediment laden water away from the system. Storm sewers which are put into use before their drainage area is stabilized can convey large amounts of sediment to natural drainageways. This practice should not be used to replace other sediment trapping devices, but it should be used in conjunction with these devices to help prevent sediment from being transported into the system and ultimately downstream or offsite.

Runoff from disturbed areas larger than one acre should be routed through a temporary sediment trap or basin.

Filter fabric is used for inlet protection when storm water flows are relatively small with low velocities.

Block and gravel filters can be used where velocities are higher.

Gravel and mesh filters can be used where flows are higher and subject to disturbance by site traffic.

Sod inlet filters may be used if sediment load in the storm water runoff is low.

Advantages

- Prevents clogging of storm drainage systems and siltation of receiving waters.
- Reduces the amount of sediment leaving the site.

Disadvantages/Problems

- May be difficult to remove collected sediment, especially under high flow conditions.
- May cause erosion elsewhere if clogging occurs.
- Practical only for low sediment, low volume flows.

Planning considerations

Installation of this measure should take place before any soil disturbance in the drainage area. Inlet protection should be used in combination with other measures, such as small impoundments or sediment traps, to provide more effective sediment removal.

The type of inlet protection device chosen depends on site conditions. Straw or hay bale barriers or sediment fences can be constructed around inlets. A small sediment basin can be excavated around the storm drain inlet. In other cases, gravel filters may be used around or directly over the storm sewer opening.

The major considerations in deciding the type of protection to be used must be based on the type of inlet, the conditions around the inlet, and the area adjacent to the inlet that may be damaged or inconvenienced because of temporary ponding of water.

Design Recommendations

- Grates and spaces of all inlets should be secured to prevent seepage of sediment-laden water.
- All inlet protection measures should include sediment sumps of 1 to 2 feet in depth, with 2:1 side slopes.
- The inlet protection device should be constructed so that any ponding resulting from the installation will not cause damage to adjacent areas or structures.
- The device must be constructed so that clean-out and disposal of trapped sediment and debris can be accomplished with little interference to construction activities.

Drainage Area

The drainage area normally should be no more than one acre.

Capacity

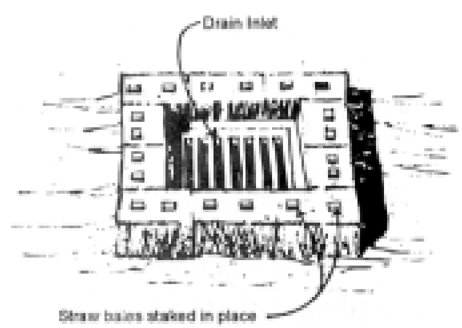
Runoff from 10-year storm must enter storm drain without bypass flow.

Types of Inlet Protection

Straw or Hay Bale Barriers

Straw or hay bale barriers can be constructed around the drain inlet.

Permeability through bales is lower than for other types of inlet protection, such as sediment fences. Provide sufficient storage space for runoff or sufficient lineal footage of bales to allow storm flow to pass through the bales.

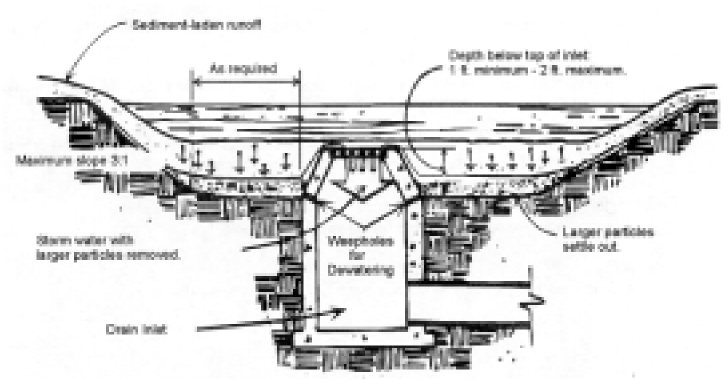


Excavated Drop Inlet Trap

This method of inlet protection is applicable where relatively heavy flows are expected and overflow capability is needed.

Applicable where the inlet drains a relatively small (less than one acre) flat area, on less than 5 percent slope. This practice works well for trapping coarse grained material. Do not place fabric under gate as the collected sediment may fall into the drain when the fabric is retrieved. This practice cannot easily be used where the area is paved because of the need for driving stakes to hold the material.

Excavated traps may be used to improve the effectiveness and reliability of other sediment traps and barriers such as fabric, or block and gravel inlet protection.



Installation:

The trap should be excavated around the inlet to provide 67 cubic feet of storage per acre of drainage area to the inlet. The trap should be no less than 1 foot deep or more than 2 feet deep when measured from the top of the inlet. Side slopes should be 3:1 or flatter.

Dimensions of the excavation should be based on the site conditions. Normally the traps are square. If there is concentrated flow being directed into the trap, however, then the trap should be rectangular with the long dimension oriented in the direction of the flow.

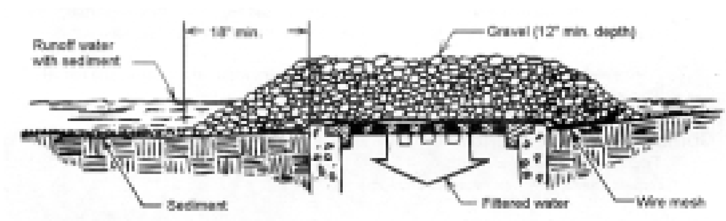
When necessary, spoil may be placed to form a dike on the downslope side of the excavation to prevent bypass flow.

Common Trouble Points

Sediment fills excavated basin and enters storm drain
Sediment-producing area too large for basin design or inlet not properly maintained.
Excessive ponding
Gravel over weep holes may be plugged with sediment. Remove debris, clear sediment, and replace gravel.
Flooding and erosion due to blockage of storm drain
Install trash guard.

Gravel and Wire Mesh Filter

Applicable where flows greater than 0.5 cfs are expected and construction traffic may occur over the inlet.



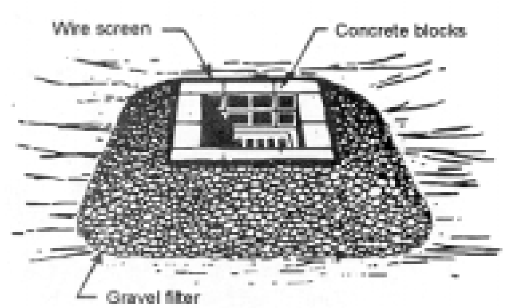
Installation

A wire mesh should be placed over the drop inlet or curb opening so that the entire opening and a minimum of 12 inches around the opening are covered by the mesh. The mesh may be ordinary hardware cloth or wire mesh with openings up to ½ inch. If more than one strip of mesh is necessary, overlap the strips. Place filter fabric over wire mesh.

Extend the filter fence/wire mesh beyond the inlet opening at least 18 inches on all sides. Place ¾ to 3-inch gravel over the filter fabric/wire mesh. The depth of the gravel should be at least 12 inches over the entire inlet opening.

Block and Gravel Inlet Protection

This method uses standard concrete block and gravel to provide a small, sturdy barrier to trap sediment at the entrance to a storm drain. It applies to both drop inlets and curb inlets where heavy flows are expected and an overflow capacity is necessary to prevent excessive ponding around the structure.



Concrete blocks are laid without mortar closely around the perimeter of the drain. Gravel is then placed around the outside of the blocks to restrict the flow and form a sediment pool. For slower drainage and therefore more settlement time, the concrete blocks could be eliminated and the device made entirely of gravel.

Pool depth should be limited to a maximum of 2 feet.

Frequent maintenance is a must for this practice.

Installation:

Place wire mesh over the drop inlet so that the wire extends a minimum of 1 foot beyond each side of the inlet structure. Use hardware cloth or comparable wire mesh with one-half inch openings. If more than one strip is necessary, overlap the strips. Place filter fabric over the wire mesh.

Place concrete blocks lengthwise on their sides in a single row around the perimeter of the inlet, so that the open ends face outward, not upward. The ends of adjacent blocks should abut. The height of the barrier can be varied, depending on design needs, by stacking combinations of blocks that are 4 inches, 8 inches, and 12 inches wide. The row of blocks should be at least 12 inches but no greater than 24 inches high.

Place wire mesh over the outside vertical face (open end) of the concrete blocks. Extend at least 12 inches around the opening to prevent aggregate from being transported through the openings in the block. Use hardware cloth or comparable wire mesh with ½ inch openings.

Pile gravel, 1-inch diameter or smaller, against the wire mesh to the top of the outside face of the blocks to control drainage rate.

Common Trouble Points

Top of structure too high

- Bypass storm flow causes severe erosion.

Blocks not placed firmly against storm drain inlet

- Scour holes develop.

Drainage area too large

- Poor trap efficiency and/or sediment overload.

Approach to drain too steep

- Causes high flow velocity and poor trap efficiency. Install excavated basin in the approach.

Sediment not removed following a storm

- Sediment enters storm drain.

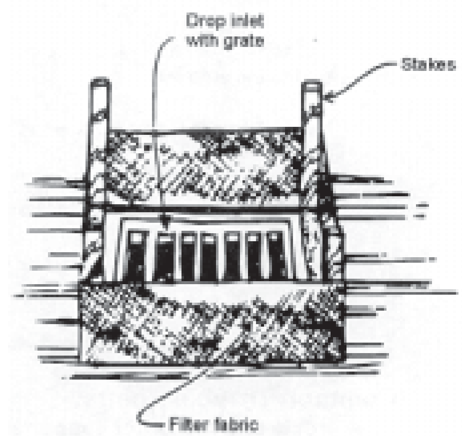
Stone in gravel donut not large enough or inside slope too steep

- Stone washes into inlet.

Maintenance

Remove and replace gravel over weep holes when drainage stops.

Fabric Drop Inlet Protection



A temporary device consisting of porous fabric supported by posts and placed around a drop inlet.

When properly braced and sealed at the bottom, the fabric restricts flow rate, forming a sedimentation pool at the approach to the inlet. The fabric allows the pool to drain slowly, protecting the storm drain from sediment.

This method of inlet protection is effective where the inlet drains a small, nearly level area with slopes generally less than 5 percent and where shallow sheet flows are expected.

The immediate land area around the inlet should be relatively flat (less than 1%) and located so that accumulated sediment can be easily removed.

This method cannot easily be used where the area is paved because of the need for driving stakes to hold the material.

Height of fabric
1.5 ft maximum, 1 foot minimum; measured from top of inlet.

Stability
Structure must withstand 1.5-foot head of water and sediment without collapsing or undercutting.

Support posts
Steel fence posts or 2 x 4-inch wood, length 3 foot minimum, spacing 3 foot maximum; top frame support recommended.

Fabric material
Synthetic, extra-strength fabric. Burlap is acceptable for short-term use only (60 days or less).

Installation:

Space support posts evenly against the perimeter of the inlet a maximum distance of 3 ft apart and drive them at least 8 inches into the ground. The stakes must be at least 3 feet long. Overflow must fall directly into the inlet and not on unprotected soil.

Build a supporting frame of 2 x 4-inch lumber, maximum height 1.5 ft above the drop inlet crest. The frame adds stability and serves as a weir to control storm overflow into the drop inlet. Alternatively, use wire fence (14 gauge minimum, with a maximum mesh spacing of 6 inches) to support fabric. Stretch fence with top level to provide uniform overflow. Extend wire 6 inches below ground.

Excavate a trench approximately 8 inches wide and 12 inches deep around the outside perimeter of the stakes.

Cut fabric from a single roll to eliminate joints. Place bottom 12 inches of fabric in trench adjacent to the drop inlet.

Fasten fabric securely to the posts and frame or support fence, if used. Overlap joints to the next post.

Backfill the trench with ¾ inch or less washed gravel all the way around.

Do not place fabric under grate as the collected sediment may fall into the drain when the fabric is retrieved.

Stabilize disturbed areas immediately after construction.

Common Trouble Points:

Posts and fabric not supported at the top
- Results in collapse of the structure.

Fabric not properly buried at bottom
- Results in undercutting.

Top of fabric barrier set too high
- Results in flow bypassing the storm inlet or collapsing structure.

Temporary dike below the drop inlet not maintained
- Results in flow bypassing storm inlet

Sediment not removed from pool
- Results in inadequate storage volume for next storm.

Fence not erected against drop inlet
- Results in erosion and undercutting.

Land slope at storm drain too steep
- Results in high flow velocity, poor trapping efficiency, and inadequate storage volume. Excavation of sediment storage area may be necessary.

Sod Drop Inlet Protection

A permanent grass sod filter area around a storm drain drop inlet in a stabilized, well vegetated area.

Where Practice Applies:

- Where the drainage area of the drop inlet has been permanently seeded and mulched and the immediate surrounding area is to remain in dense vegetation.
- This practice is well suited for lawns adjacent to large buildings.
- The drainage area should not exceed 2 acres,
- The entrance flow velocity must be low, and
- The general area around the inlet should be planned for vegetation.

Other Inlet Protection Practices

There are several types of manufactured inlet filters and traps which have different applications dependent upon site conditions and type of inlet. One is a catchbasin filter that prevents sediments and other contaminants from entering storm drainage systems. The catchbasin filter is inserted in the catchbasin just below the grating. The catchbasin filter is equipped with a sediment trap and up to three layers of a fiberglass filter material.

This is a changing field. New products are being developed and brought to the market. For the most recent information see a trade journal such as Erosion Control or Land and Water.

Maintenance

All trapping devices and the structures they protect should be inspected after every rain storm and repairs made as necessary.

Sediment should be removed from the trapping devices after the sediment has reached a maximum of one half the depth of the trap.

Sediment should be disposed of in a suitable area and protected from erosion by either structural or vegetative means.

Temporary traps should be removed and the area repaired as soon as the contributing drainage area to the inlet has been completely stabilized.

Systems using filter fabric

Inspections should be made on a regular basis, especially after large storm events. If the fabric becomes clogged, it should be replaced.

Systems using stone filters

If the stone filter becomes clogged with sediment, the stones must be pulled away from the inlet and cleaned or replaced. Since cleaning of gravel at a construction site may be difficult, an alternative approach would be to use the clogged stone as fill and put fresh stone around the inlet.

References

Massachusetts Department of Environmental Protection, Office of Watershed Management, Nonpoint Source Program, Massachusetts ***Nonpoint Source Management Manual***, Boston, Massachusetts, June, 1993.

Minnick, E. L., and H. T. Marshall, ***Stormwater Management and Erosion Control for Urban and Developing Areas in New Hampshire,*** Rockingham County Conservation District, August 1992.

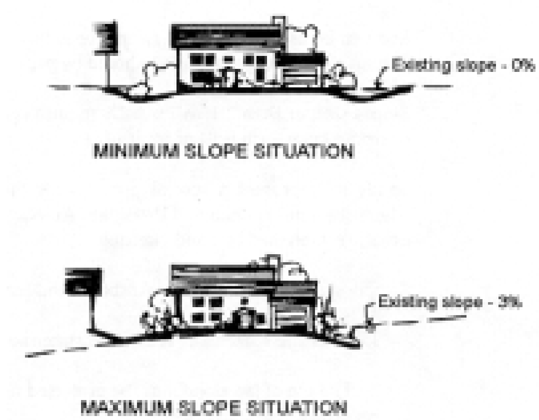
North Carolina Department of Environment, Health, and Natural Resources, ***Erosion and Sediment Control Field Manual***, Raleigh, NC, February 1991.

U.S. Environmental Protection Agency, ***Storm Water Management For Construction Activities***, EPA-832-R-92-005, Washington, DC, September, 1992.

Washington State Department of Ecology, ***Stormwater Management Manual for the Puget Sound Basin***, Olympia, WA, February, 1992.

Land Grading and Stabilization

Using engineering techniques or vegetative practices, or a combination of both, to provide surface drainage and control erosion and sedimentation while reshaping and stabilizing the ground surface to provide more suitable sites for buildings and other facilities, or maintain temporary stockpiles.



Where Practice Applies

This practice applies where the existing ground surface is regraded, new cut or fill slopes are created, or existing slopes or ground surfaces would otherwise be unstable or subject to erosion.

Planning Considerations

Provisions should be made to safely conduct surface runoff to storm drains, protected outlets, or to a stable watercourse to insure that the runoff will not damage slopes or other graded areas.

Wherever possible runoff water should be diverted away from the top of cut and fill slopes to stable outlets or grade control structures.

Waterways, diversions, grade stabilization structures, terraces, pipe drains, flumes, subsurface drains, or rock fills are some of the practices that may find use in slope stabilization. Bioengineering practices, combining vegetative and mechanical practices, also have a place.

Cuts, Fills, and Slopes

Compaction can be a major factor in erosion control for fill slopes. In addition to other compaction controls required by the nature of the project, the minimum criterion recommended for successful erosion control on fill slopes is to compact the uppermost one foot of fill to at least 85 percent of the maximum unit weight (based on the modified AASHTO compaction test). This is usually accomplished by running heavy equipment over the fill.

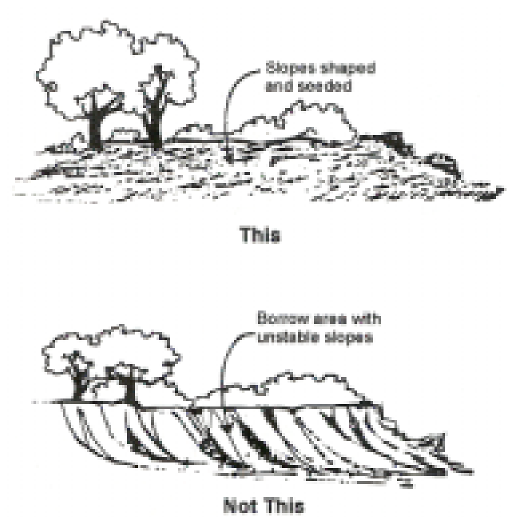
On cut slopes ground water seepage causes undercutting and soil slippage. Subsurface drains, a layer of crushed rock, or other measures may be necessary.

Slope gradient is an important factor in the success of vegetative restabilization measures. Normal tillage equipment cannot be used to prepare a seedbed on slopes 2:1 or steeper. Storm water runoff will result in the loss of seeds, fertilizer, and soil.

Sod can be used to stabilize steep slopes instead of seeding where grades are not more than 2:1. Sod on slopes steeper than 3:1 should be pegged.

Slopes steeper than 2:1 will usually require special stabilization measures such as a crushed rock or riprap layer, crib wall or revetment.

Sandy soils present a special problem for the establishment of vegetation, especially in areas where the sand is deep and droughty. American beachgrass is one solution to this problem. It is usually established by hand planting.



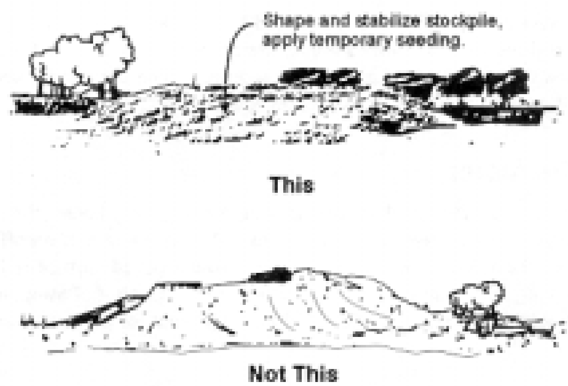
Borrow areas should be left stable.

Steeply sloped areas such as lakeshores and road banks involve three special considerations:

- To insure reasonable success in stabilization, bank slopes should be 2:1 or flatter.
- The toe of the slope must be protected from undercutting by mechanical means where necessary.
- Water seeping from the face of the slope should be intercepted by a drainage system.

Borrow and Stockpile Areas

Borrow areas, especially those that are located off the development site, must be considered in erosion and sedimentation control planning. Borrow areas, as well as stockpile and spoil areas, must be stabilized.



Leave stockpiles in stable condition.

Borrow and stockpile areas present the same set of problems for the control of erosion and sedimentation as exposed cut and fill slopes. Runoff should be diverted from the face of the slopes which are exposed in the excavation process. The runoff must then be conveyed in stabilized channels to stable disposal points.

The measures used to control erosion on slopes should also be used in borrow areas. Only those sections of the borrow area which are currently needed to supply fill should be stripped. Immediately after the required fill has been taken, the exposed area should be stabilized.

If final grading is delayed, temporary seeding should be used. By properly timing the disturbance of the natural cover in the borrow area in carefully planned phases, the area of exposed soil and the duration of exposure is reduced and, therefore, erosion losses are reduced.

Topsoil from borrow areas is usually stripped and stockpiled for later redistribution on the disturbed area. These stockpiles should be located on the uphill side of the excavated area wherever possible so that they can act as diversions. Stockpiles should be shaped and seeded with temporary cover.

Where borrow areas are off the development site, a separate system for trapping sediment from the area is needed.

After the excavation is complete, borrow areas should be regraded to insure proper drainage and to blend the borrow area with the surrounding topography. Stockpiled topsoil is then redistributed and permanent vegetative cover established.

Exposed Surfaces

Although erosion rates on steep exposed slopes are higher than on flat or gently sloping areas, all areas of exposed soil are vulnerable to erosion. If erosion control is ignored on larger areas of nearly flat or gently sloping land, it will be possible for significant amounts of soil to be eroded. Clearing, grading, and vegetative restabilization in these areas can be timed so that the extent of exposed area and the duration of exposure is minimized. These areas require prompt vegetative restabilization. Temporary seeding or mulching is required where larger areas will not be permanently stabilized within recommended time limits. Diversions, sediment barriers, or traps constructed on the lower side of large disturbed areas should be used to intercept and collect sediment.

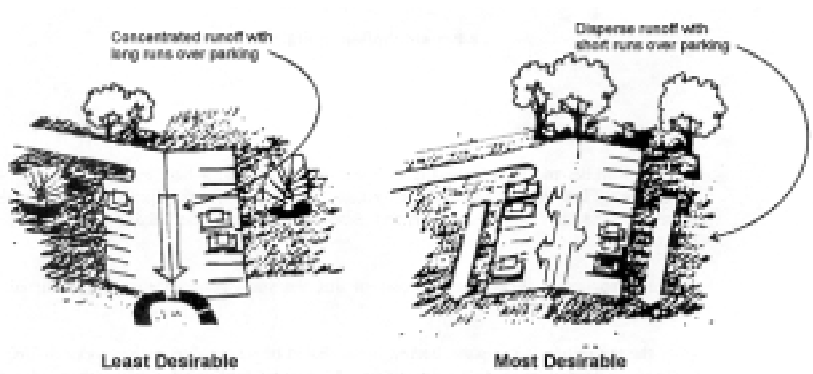
Right-of-ways and parking areas that are being prepared for paving must be protected from rainfall and runoff. Diversions should be constructed to protect these areas from runoff before clearing and grading begin.

Areas that are being prepared for paving should be properly compacted because compaction makes the exposed surface area less vulnerable to erosion. Cleared right-of-ways may be covered with crushed aggregate to reduce erosion. If right-of-ways will not be used for construction traffic, they can be seeded with temporary cover.

Gravel or stone filter berms should be used at intervals along a right-of-way to intercept runoff and direct it to stabilized areas, drainageways, or enclosed drainage system inlets. Filter berms slow runoff, filter it, and collect sediment. The berms will need some continuing maintenance, but can be crossed by construction equipment.

Paved Surfaces

An increase in paved surface area on a site greatly boosts the rate of site runoff. For example, a 20 percent increase in paved area can double the rate of runoff during a heavy rainfall. In addition, the velocity of runoff moving across a paved surface is higher than the velocity of runoff moving across an area of exposed earth of vegetation. Pavement provides very little resistance to flow and does not allow any infiltration (except for porous pavement).



Construction Areas and Eroding Areas

Types of plantings

When erosion or sediment control is of primary and immediate concern, these areas are usually initially stabilized by seeding grass cover. When necessary, the site should be prepared by seeding temporary vegetative cover. Jute netting or anchored mulch should be used in conjunction with seeding at critical locations where water concentrates.

Seeding mixtures

When dense plant cover is needed for erosion and sediment control, or for appearances, seedings of enduring herbaceous species should be used. See the Permanent Seeding and Temporary Seeding practices. One-half to one bushel of oats, or 1 to 1 ½ bushels of rye should usually be added to the basic mixture for quick cover.

Mulching

Where plantings are on areas subject to mulch removal by wind or water flows, the mulch should be anchored. Mulched areas should be checked periodically and immediately after severe storms for damage until the desired purpose of the mulching is achieved. Any damaged areas should be repaired as soon as discovered.

Design Recommendations

Cut or fill slopes which are to be vegetated should not be steeper than 2 horizontal to 1 vertical. If a slope is to be mowed, it should be 3:1 or flatter. Slopes of materials not to be vegetated should be at the safe angle of repose for the materials encountered.

Provisions should be made to safely conduct surface water to storm drains or suitable natural water courses and to prevent surface runoff from damaging cut faces and fill slopes.

Terraces or diversions should be provided whenever the height of the cut or fill exceeds 20 feet. The “benches” should divide the slope face as equally as possible and should convey the water into stable outlets. Benches should be kept free of sediment during all phases of development.

Seeps or springs encountered during construction should be controlled by subsurface drains or other appropriate methods.

Subsurface drainage should be provided in areas having a high water table, to intercept seepage that would affect slope stability, building foundations, or create undesirable wetness.

Excavations should not be made so close to property lines as to endanger adjoining property without supporting and protecting such property from erosion, sliding, settling, or cracking.

No fill should be placed where it will slide or wash onto the premises of another or be placed adjacent to the bank of a channel so as to create bank failure or reduce the natural capacity of the stream.

Fills should consist of material from cut areas, borrow pits, or other approved sources.

Protective slopes around buildings should be planned to slope away from foundations and water supply wells to lower areas, drainage channels, or waterways. The minimum horizontal length should be 10 feet, except where restricted by property lines.

The minimum vertical fall of protective slopes should be 6 inches, except that the vertical fall at the high point at the upper end of a swale may be reduced to 3 inches, if a long slope toward a building or from a nearby high bank will not exist.

Minimum gradients should be 1/16 inch per foot (1/2 percent) for concrete or other impervious surfaces and ¼ inch per foot (2 percent) for pervious surfaces.

Maximum gradient of protective slopes should be 2 ½ inches per foot (21 percent) for a minimum of 4 feet away from all building walls, except where restricted by property lines.

All graded areas should be permanently stabilized immediately following final grading.

Site plans should show the location, slope, cut, fill, and finish elevation of the surfaces to be graded and the auxiliary practices for safe disposal of runoff water, slope stabilization, erosion control, and drainage such as waterways, lined, ditches, diversions, grade stabilization structures, retaining walls, and surface and subsurface drains.

Construction Recommendations

Areas to be graded should be cleared and grubbed of all timber, logs, brush, rubbish, and vegetable matter that will interfere with the grading operation. Topsoil should be stripped and stockpiled for use on critical disturbed areas for establishment of vegetation. Cut slopes to be topsoiled should be thoroughly scarified to a minimum depth of 3 inches prior to placement of topsoil.

Fill materials should be generally free of brush, rubbish, rocks, and stumps. Frozen materials or soft and easily compressible materials should not be used in fills intended to support buildings, parking lots, roads, conduits, or other structures.

Earth fill intended to support structural measures should to be compacted to a minimum of 90 percent of standard Proctor test density with proper moisture control, or as otherwise specified by the engineer responsible for design. Compaction of other fills should be to the density required to control sloughing, erosion or excessive moisture content.

Maximum thickness of fill layers prior to compaction should not exceed 9 inches.

Grading should generally be done to a tolerance of within 0.2 foot of planned grades and elevations. Allowances may be made for topsoil, paving, or other surface installations.

All disturbed areas should be free draining, left with a neat and finished appearance, and should be protected from erosion. (See applicable vegetative standards.)

Maintenance

All slopes should be checked periodically to see that vegetation is in good condition. Any rills or damage from erosion and animal burrowing should be repaired immediately to avoid further damage.

If seeps develop on the slopes, the area should be evaluated to determine if the seep will cause an unstable condition. Subsurface drains or a gravel mulch may be required to solve seep problems.

Diversions, berms, and waterways should be checked to see that they are functioning properly. Problems found during the inspections should be repaired promptly.

Areas requiring revegetation should be repaired immediately.

Slopes should be limed and fertilized as necessary to keep vegetation healthy.

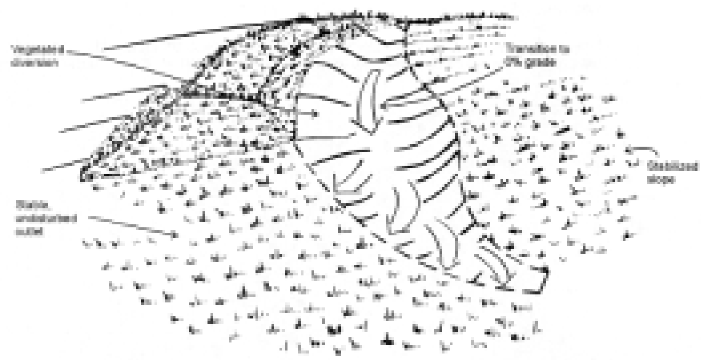
Control undesirable vegetation such as weeds and woody growth to avoid bank stability problems in the future.

References

Massachusetts Department of Environmental Protection, Office of Watershed Management, Nonpoint Source Program, ***Massachusetts Nonpoint Source Management Manual***, Boston, Massachusetts, June, 1993.

Minnick, E. L., and H. T. Marshall, ***Stormwater Management and Erosion Control for Urban and Developing Areas in New Hampshire***, Rockingham County Conservation District, August 1992.

Level Spreader



A level spreader is an excavated depression constructed at zero percent grade across a slope. The level spreader changes concentrated flow into sheet flow and then outlets it onto stable areas without causing erosion. It allows concentrated runoff to be discharged at non-erosive velocities onto natural or man-made areas that have existing vegetation capable of preventing erosion. An example would be at the outlet of a diversion or a waterway.

Where Practice Applies

- Where it can be constructed on undisturbed soils and a level lip can be installed without filling.
- Where the area directly below the spreader is stabilized by existing vegetation
- Where water will not re-concentrate immediately below the spreader, and water can be released in sheet flow down a stabilized slope without causing erosion.
- Where there is at least 100 feet of vegetated area between the spreader and surface waters.
- Where the area below the spreader lip is uniform with a slope of 10 percent or less and is stable for anticipated flow conditions.
- Where there will be no traffic over the spreader.

Advantages

- Level spreaders are relatively low cost structures designed to release small volumes of water safely.
- Level spreaders disperse the energy of concentrated flows, reducing erosion potential and encouraging sedimentation.

Disadvantages/Problems

If the level spreader has any low points, flow tends to concentrate there. This concentrated flow can create channels and cause erosion. If the spreader serves as an entrance to a water quality treatment system, short-circuiting of the forebay may happen and the system will be less effective in removing sediment and particulate pollutants.

Planning Considerations

Diversions and waterways need a stable outlet for concentrated stormwater flows. The level spreader can be used for this purpose if the runoff is relatively free of sediment. If properly constructed, the level spreader will significantly reduce the velocity of concentrated stormwater and spread it uniformly over a stable undisturbed area.

Placement of the level spreader must allow the water flowing over the level section to leave the structure as a uniform, thin film of water. The structure should outflow onto naturally vegetated areas whenever possible. The creation of a uniform level lip for the water to spread over is critical.

Particular care must be taken during construction to ensure that the lower lip of the structure is level. If there are any depressions in the lip, flow will tend to concentrate at these points and erosion will occur, resulting in failure of the outlet. This problem may be avoided by using a grade board or a gavel lip over which the runoff must flow when exiting the spreader. Regular maintenance is essential for this practice.

Water containing high sediment loads should enter a sediment trap before release in a level spreader.

Design Recommendations

Drainage area should be limited to five acres.

The grade of the channel for the last 20 feet of the conservation practice entering the level spreader should be no steeper than 1 percent.

The level spreader should be flat (“0 percent” grade) to ensure uniform spreading of storm runoff.

The design length for a level spreader should be no more than 0.5 cfs per foot of level section, based on the peak rate of flow from the contributing erosion control or stormwater management practice. The minimum length of the spreader should be 5 feet and the maximum length 50 feet.

The width of the spreader should be at least 6 feet.

The depth of the spreader as measured from the lip should be at least 6 inches and it should be uniform across the entire length.

The spreader shall be stabilized with an appropriate grass mixture. The spreader should be mulched if necessary for the establishment of good quality vegetation.

The level lip may be protected with an erosion stop and jute or excelsior matting. The erosion stop should be placed vertically a minimum of six inches deep in a slit trench one foot back from the crest of the level lip and parallel to the lip. The erosion stop should extend the entire length of the level lip. Two strips of jute or excelsior matting can be placed along the lip. Each strip should overlap the erosion stop by at least six inches.

The area downslope should have a complete vegetative cover sufficiently established to be erosion resistant.

Maintenance

- The level spreader should be checked periodically and after every major storm.
- Any detrimental sediment accumulation should be removed.
- If rilling has taken place on the lip, the damage should be repaired and re-vegetated.
- Vegetation should be mowed occasionally to control weeds and encroachment of woody vegetation. Clippings should be removed and disposed of outside the spreader and away from the outlet area.
- Fertilization should be done as necessary to keep the vegetation healthy and dense.
- The spreader should be inspected after every runoff event to ensure that it is functioning correctly.

References

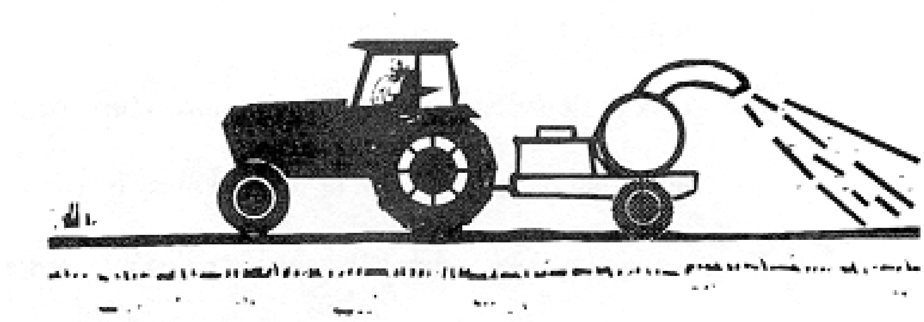
Massachusetts Department of Environmental Protection, Office of Watershed Management, Nonpoint Source Program, ***Massachusetts Nonpoint Source Management Manual***, Boston, Massachusetts, June, 1993.

Minnick, E. L., and H. T. Marshall, ***Stormwater Management and Erosion Control for Urban and Developing Areas in New Hampshire***, Rockingham County Conservation District, August 1992.

Washington State Department of Ecology, ***Stormwater Management Manual for the Puget Sound Basin***, Olympia, WA, February, 1992.

Mulch and Netting

Application of a protective blanket of straw or other plant residue, gravel or synthetic material to the soil surface.



Purpose

To provide immediate protection to exposed soils during the period of short construction delays, or over winter months through the application of plant residues, or other suitable materials, to exposed soil areas.

Mulches also enhance plant establishment by conserving moisture and moderating soil temperatures. Mulch helps hold fertilizer, seed, and topsoil in place in the presence of wind, rain, and runoff and maintains moisture near the soil surface.

In addition to stabilizing soils, mulching can reduce the speed of storm water runoff over an area.

Where Practice Applies

- In areas which have been seeded either for temporary or permanent cover, mulching should immediately follow seeding.
- Areas which cannot be seeded because of the season, or are otherwise unfavorable for plant growth.
- Mulch around plantings of trees, shrubs, or ground covers to stabilize the soil between plants.
- In an area of greater than 2:1 slope, mulching should immediately follow seeding.

Advantages

- Mulching offers instant protection to exposed areas.
- Mulches conserve moisture and reduce the need for irrigation.
- Neither mulching nor matting require removal; seeds can grow through them unlike plastic coverings.
- This is one of the most important, effective, and economical erosion-control practices.

Disadvantages/Problems

- Care must be taken to apply mulch at the specified thickness, and on steep slopes mulch must be supplemented with netting.
- Thick mulches can reduce the soil temperature, delaying seed germination.
- Mulch can be easily blown or washed away by runoff if not secured.
- Some mulch materials such as wood chips may absorb nutrients necessary for plant growth.
- Mulches such as straw, which are often applied to areas after grading must then be removed and either composted or landfilled.

Planning Considerations

Mulches are applied to the soil surface to conserve a desirable soil property or to promote plant growth. A surface mulch is one of the most effective means of controlling runoff and erosion on disturbed land.

Mulches can increase the infiltration rate of the soil, reduce soil moisture loss by evaporation, prevent crusting and sealing of the soil surface, modify soil temperatures, and provide a suitable microclimate for seed germination.

Organic mulch materials, such as straw, wood chips, bark and wood fiber, have been found to be the most effective, although straw is preferred.

Wood chips and bark are effective for use around trees and shrubs.

It is important to properly anchor grass or straw mulch materials so they are not blown away by wind or washed away by flowing water.

On steep slopes and critical areas such as waterways, use netting or anchoring with mulch to hold it in place.

"Mechanical mulches" such as gravel may be used in critical areas where conditions preclude the use of vegetation for permanent stabilization.

The choice of materials for mulching will be based on the type of soil to be protected, site conditions, season, and economics. It is especially important to mulch liberally in mid-summer and prior to winter, and at locations on cut slopes and southern slope exposures.

Materials and Installation

Mulch Material	Quality Standards	Application Rate / 1,000 sq. ft.	Application Rate /Acre	Depth of Application	Remarks
Sawdust - green or composted	Free from objectinable coarse material	83-500 cu.ft.	- - -	1-7"	Most effective as a mulch around ornamentals, small fruits& other nursery stock. Requires 30-35 lbs. N/ton to prevent N deficiency while decaying mulch. One cu. ft. weighs 25 lbs.
Wood Chips or Shavings	Green or airdried. Free of objectionable material	500-900 lbs	10-20 tons	2-7 "	Has about the same use and application as sawdust, but requires less N/ton (10-12 lbs). Resistant to wind blowing. Decomposes slowly.
Wood Excelsior	Green or air-dried burred wood fibers	90 lbs (one bale)	2 tons	- - -	Decomposes slowly. Subject to some wind blowing. Packaged in 80-90 lb. bales.
Wood Fiber Cellulose (partially digested wood fibers)	Made form natural wood, usually with green dye & dispersing agent added	50 lbs	2000 lbs	- - -	Apply with hydromulcher. No tie-down required. Less erosion control provided than 2t hay or straw.
Compost or Manure	Well shredded, free of excessive coarse materials	400-600 lbs	8-10 tons	- - -	Use straw manure where erosion control is needed. May create problem with weeds. Excellent moisture conserver. Resistant to wind blowing.
Cornstalks, shredded or chopped	Airdried, shredded into 8-12" lengths	150-300 lbs	4-6 tons	- - -	Effective for erosion control,relatively slow to decompose. Excellent for mulch on crop fields. Resistant to wind blowing.

Mulch Material	**Quality Standards**	**Application Rate / 1,000 sq. ft.**	**Application Rate /Acre**	**Depth of Application**	**Remarks**
Gravel, crushed stone or slag	Washed, 1 1/2" max.	9 cu. yds	- - -	3'	Excellent mulch for short slopes and around woody plants and ornamentals. Frequently used over black plastic for better weed control.
Hay or Straw	Air-dried, free of undesirable seeds & materials	90-100 lbs. (2-3 bales)	2 tons (100-120 bales)	Cover about 90% of surface	Use straw where mulch is maintained for more than 3 months. Subject to wind blowing unless anchored. Most commonly used mulching material. Best microenvironment for germinating seeds.
Peat Moss	Dried, compressed free of coarse materials	200-400 cu. ft	---------	2"-4"	Most effective as a mulch around ornamentals. Subject to wind blowing unless kept wet. 100 lbs. bales (6 cu.ft.). Excellent moisture holding capacity.
Jute Twisted Yarn	Undyed, unbleached plain weave. Warp: 78 ends/yd. Weft: 41 ends/yd 60-90 lbs/roll	48"x50 yds or 48"x75 yds.	-------	-----	Use without additional mulch. Tie down as per manufacturing specification.
Excelsior Wood Fiber Mats	Interlocking web of excelsior fibers with photodegradable plastic netting	48"x100" 2-sided plastic; 48"x180" 1-sided plastic	------	-----	Use without additional mulch. Excellent for seeding establishment. Tie down as per manufacturers specs. Appox. 72 lbs/roll for Excelsior with plastic on both sides. Use 2-sided plastic for center, plastic for centerline of waterways.

Mulch Material	Quality Standards	Application Rate / 1,000 sq. ft.	Application Rate /Acre	Depth of Application	Remarks
Glass Fiber	1/4" thick, 7/16" dia. holes on 1" centers: 56 lb rolls	72'x30 yds.	----	----	Use without additional mulch. Tie down with T-bars as per manufacturers specifications.
Plastic	2-4 mils	variable	-----	-----	Use black for weed control. Effective moisture conservation and weed control for small fruits and ornamentals
Filter Fabrics	Woven or Spun	variable	------	------	------
Straw or coconut fiber or combination	Photodegradable plastic net on one or two sides	Most are 6.5'x83.5'	81 rolls	-----	Designed to tolerate higher velocity water flow, centerlines of waterways. 60 sq. yds. per roll.

Mulch Anchoring Guide

Anchoring Method or Material	Kind of Mulch To Be Anchored	How To Apply
Manual		
Peg & Twine	Hay or straw	After mulching, divide areas into blocks approximately 1 sq. yd. in size. Drive 4-6 pegs per block to within 2" to 3" soil surface. Secure mulch to surface by stretching twine between pegs in criss-cross pattern on each block. Secure twine around each peg with 2 or more turns. Drive pegs flush with soil where mowing and maintenance is plannned.
Mulch Netting	Hay or straw	Staple the light-weight paper, jute, wood fiber, or plastic nettings to soil surface according to manufacturers recommendations. Should be biodegradable. Most products not suitable for foot traffic.
Soil & Stone	Plastic	Plow a single furrow along edge of area to be covered with plastic, fold about 6" of plastic into the furrow and plow furrow slice back over plastic. Use stones to hold plastic down in other places as needed.
Cut-in	Hay or straw	Cut mulch into soil surface with square edged spade. Make cuts in contour rows spaced 18" apart. Most sucessful on contour in sandy soils

Anchoring Method or Material	Kind of Mulch To Be Anchored	How To Apply
Mechanical		
Asphalt Spray (emulsion)	Compost, wood chips, wood shavings, hay or straw	Apply with suitable spray equipment using the following rates; Asphalt emulsion: on slopes use 200 gal/acre, on level, use 150 gal/acre Liquid asphalt: (rapid, medium, or slow setting) 0.10 gal per square yd. 400 gal/acre
Wood Cellulose Fiber	Hay or straw	Apply with hydroseeder immediately after mulching. Use 750 lbs. wood fiber per acre. Some products contain an adhesive material.
Pick Chain	Hay or straw, manure compost	Use on slopes steeper than 3:1. Pull across slopes with suitable power equipment.
Mulch Anchoring tool or Disk	Hay or straw, manure/mostly straw	Apply mulch and use a mulch anchoring tool. When a disk (smooth) is used, set in straight position and pull across slope with suitable power equipment. Mulch material should be tucked into soil surface about 3".
Chemical	Hay or straw	Apply Terra Tack AR at 120 lbs/acre in 480 gal. of water or Aerospray 70 (60 gal/acre) according to manufacturer's instructions. A 24 hr. curing period and a soil temp higher than 45 degrees F. are required.

Common Trouble Points

Inadequate Coverage
Results in erosion, washout, and poor plant establishment

Appropriate tacking agent not applied, or applied in insufficient amount
Mulch is lost to wind and runoff.

Channel grade and liner not appropriate for amount of runoff
Results in erosion of channel bottom. Plan modification may be required.

Hydromulch applied in winter
Results in deterioration of mulch before plants can become established.

Maintenance

Inspect after rainstorms to check for movement of mulch or erosion. If washout, breakage, or erosion occurs, repair surface, reseed, remulch, and install new netting.

Straw or grass mulches that blow or wash away should be repaired promptly.

Blanket mulch that is displaced by flowing water should be repaired as soon as possible.

If plastic netting is used to anchor mulch, care should be taken during initial mowings to keep the mower height high. Otherwise, the netting can wrap up on the mower blade shafts. After a period of time, the netting degrades and becomes less of a problem.

Continue inspections until vegetation is well established.

References

Gaffney, F.B., Dickerson, J.A., Myers, R.E., Hoyt, D.K., Moonen, H.F., Smith, R.E., ***A Guide To: Conservation Plantings on Critical Areas for New York***, U.S. Department of Agriculture, Soil Conservation Service, Syracuse, NY, June, 1991.

Massachusetts Department of Environmental Protection, Office of Watershed Management, Nonpoint Source Program, ***Massachusetts Nonpoint Source Management Manual***, Boston, Massachusetts, June, 1993.

Minnick, E. L., and H. T. Marshall, ***Stormwater Management and Erosion Control for Urban and Developing Areas in New Hampshire,*** Rockingham County Conservation District, August 1992.

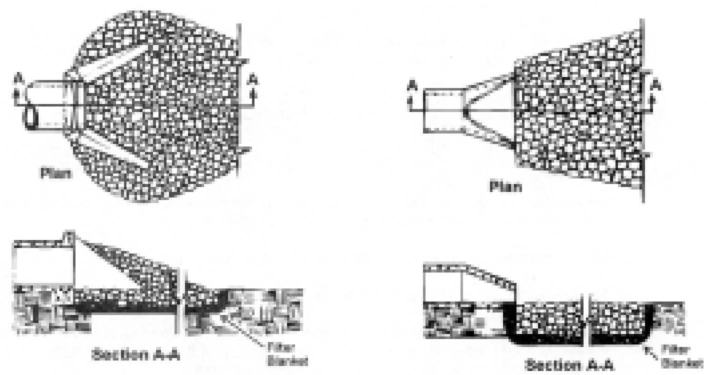
North Carolina Department of Environment, Health, and Natural Resources, ***Erosion and Sediment Control Field Manual***, Raleigh, NC, February 1991.

U. S. Environmental Protection Agency, ***Storm Water Management For Construction Activities***, EPA-832-R-92-005, Washington, DC, September, 1992.

Washington State Department of Ecology, ***Stormwater Management Manual for the Puget Sound Basin***, Olympia, WA, February, 1992.

Outlet Protection and Stabilization

A structure designed to control erosion at the outlet of a channel or conduit by reducing the velocity of flow and dissipating the energy.



Pipe Outlet to Well-defined Channel

Pipe Outlet to Flat Area; No Well-defined Channel

Where Practice Applies

- Outlet protection should be installed at all pipe, culverts, swales, diversions, or other water conveyances where the velocity of flow may cause erosion at the pipe outlet and in the receiving channel.
- Outlet protection should also be used at outlets where the velocity of flow at the design capacity may result in plunge pools.
- Outlet protection should be installed early during construction activities, but may be added at any time, as necessary.

Advantages

- Plunge pools, which can develop unless outlet protection is provided, may severely weaken the embankment and thus threaten its stability.
- Protection can prevent scouring at a culvert mouth and thus prevent gully erosion which may gradually extend upstream.

Disadvantages/Problems

- Some types of structures may be unsightly.
- Sediment removal may be difficult.

Planning Considerations

Erosion at the outlet of channels, culverts, and other structures is common and can cause structural failure with serious downstream problems.

A riprap lined apron is the most commonly used structure for this purpose, because it has relatively low cost and can be installed easily on most sites.

Other types of outlet stabilization structures include riprap stilling basins, concrete impact basins, and paved outlets.

Design Criteria

Capacity - Peak runoff from 10-year storm.
Apron - As shown in plans, set on zero grade, aligned straight, with sufficient length to dissipate energy.
Foundation - Extra-strength filter fabric or well-graded gravel filter layer, 6 inches thick, minimum.
Material - Hard, angular, and highly weather-resistant stone (riprap) with specific gravity at least 2.5. Stone size as specified in plans.
Thickness - At least 1.5 times the maximum stone diameter.

Installation

Excavate subgrade below design elevation to allow for thickness of filter and riprap. Install riprap to minimum thickness of 1.5 times maximum stone diameter. Final structure should be to lines and elevations shown in plans.

Construct apron on zero grade. If there is no well-defined channel, cross section may be level or slightly depressed in the middle. In a well-defined channel, extend riprap and filter to the top of the bank or as shown on plans. Blend riprap smoothly to the surrounding land.

Apron should be straight and properly aligned with the receiving stream. If a curve is necessary to fit site conditions, curve the apron near the upstream end.

Compact any fill used in the subgrade to the density of the surrounding undisturbed material.

Subgrade should be smooth enough to protect fabric from tearing.

Install a continuous section of extra-strength filter fabric on smooth, compacted foundation.

Protect filter fabric from tearing while placing riprap with machinery. Repair any damage immediately by removing riprap and installing another section of filter fabric. Upstream section of fabric should overlap downstream section a minimum of one foot.

Make sure top of riprap apron is level with receiving stream or slightly below it. Riprap should not restrict the channel or produce an overfall.

Immediately following installation, stabilize all disturbed areas with vegetation as shown in plans.

Common Trouble Points

Foundation not excavated deep enough or wide enough
Riprap restricts flow cross section, resulting in erosion around apron and scour holes at outlet.

Riprap apron not on zero grade
Causes erosion downstream.

Stones too small or not properly graded
Results in movement of stone and downstream erosion.

Riprap not extended far enough to reach a stable section of channel
Results in downstream erosion.

Appropriate filter not installed under riprap
Results in stone displacement and erosion of foundation.

Maintenance

Inspect riprap outlet structures after heavy rains for erosion at sides and ends of apron and for stone displacement.

Rock may need to be added if sediment builds up in the pore spaces of the outlet pad.

Make repairs immediately using appropriate stone sizes. Do not place stones above finished grade.

References

Massachusetts Department of Environmental Protection, Office of Watershed Management, Nonpoint Source Program, Massachusetts ***Nonpoint Source Management Manual Boston***, Massachusetts, June, 1993.

North Carolina Department of Environment, Health, and Natural Resources, ***Erosion and Sediment Control Field Manual,*** Raleigh, NC, February 1991.

U. S. Environmental Protection Agency, ***Storm Water Management for Construction Activities***, EPA-832-R-92-005, Washington, DC, September, 1992.

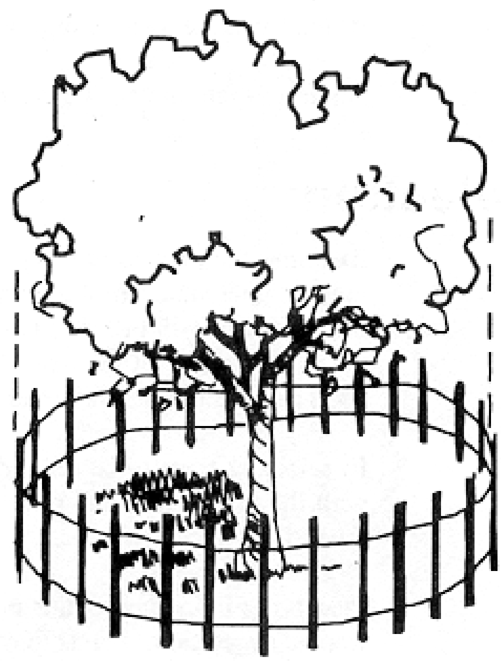
Washington State Department of Ecology, ***Stormwater Management Manual for the Puget Sound Basin***, Olympia, WA, February, 1992

Preserving Natural Vegetation

Minimizing exposed soils and consequent erosion by clearing only where construction will occur.

Where Practice Applies

Natural vegetation should be preserved whenever possible, but especially on steep slopes, near perennial and intermittent watercourses or swales, and on building sites in wooded areas.



Advantages

Preserving natural vegetation will:

- Save money on site stabilization
- Help reduce soil erosion.
- Beautify an area.
- Save money on landscaping costs.
- Provide areas for wildlife.
- Possibly increase the value of the land.
- Provide buffers and screens against noise.

Preserving natural vegetation also moderates temperature changes and provides shade and cover habitat for surface waters and land. Increases in stream water temperature tend to lower the dissolved oxygen available for aquatic life.

Disadvantages/Problems

Saving individual trees can be difficult, and older trees may become a safety hazard.

Planning Considerations

New development often takes place on tracts of forested land. Building sites are often selected because of the presence of mature trees. Unless sufficient care is taken and planning done, however, much of this resource is likely to be destroyed in the interval between buying the property and completing construction. It takes 20 to 30 years for newly planted trees to provide the benefits for which we value trees so highly.

Natural vegetation can be preserved in natural clumps or as individual trees, shrubs and vines.

Selection

Examine the area to identify trees to be saved: trees with unique or unusual form, trees which may be uncommon in the area, desirable shade trees and trees for screening purposes. Look for healthy trees with full green crowns. The length of the annual twig growth gives an indication of the general vigor of the tree. Trees with broken tops or with many dead branches are usually not good risks. Badly scarred trees are also unsuitable.

In selecting trees to be retained, care must also be used to make certain they will not interfere with the installation and maintenance of utilities such as electric and telephone lines, water and sewer lines and driveways.

Preserving individual plants is more difficult because equipment is generally used to remove unwanted vegetation. Points to consider when attempting to save individual plants are:

Value

Is the plant worth saving? Consider the location, species, size, age, vigor, and the work involved. Local governments may also have ordinances to save natural vegetation and trees.

Desirability

Is the tree or shrub a desirable plant? Is it shallow-rooted, do the roots seek water, or are insects and disease a problem? Shallow-rooted plants can cause problems in the establishment of lawns or ornamental plants. Water-seeking roots can block sewer and tile lines. Insects and diseases can make the plant undesirable. This is especially true with aphids on alder and maple.

Age and size

Old or large plants do not generally adapt to changes in environment as readily as young plants of the same species. Usually, it is best to leave trees which are less than 40 years of age. Some hardwoods mature at approximately 50 years of age. After maturity they rapidly decline in vigor. Conifers, after 40 years of age, may become a safety hazard due to the possibility of breakage or blowdown, especially where construction has left only a few scattered trees in an area that was formerly dense woods.

While old large trees are sometimes desirable, the problem of later removal should be considered. Local governments, however, may have requirements to preserve older, larger specimen trees. It is expensive to cut a large tree and to remove the tree and stump from a developed area. Thinning some branches from trees can provide avenues for wind and hence lessen the “sail” effect.

Tree Preservation

Clearly flag or mark areas around trees that are to be saved. It is preferable to keep ground disturbance away from the trees at least as far out as the dripline.

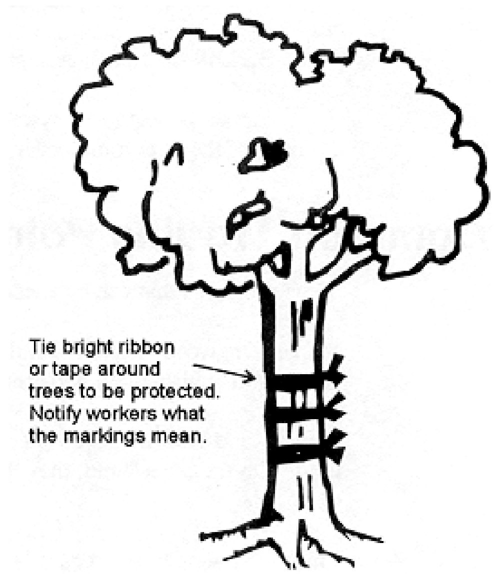
Barriers

If possible, place a barrier around the trees. Bulldozers are notorious for damaging trees. Besides skinning bark from tree trunks, their tracks severely damage tree roots which are close to the surface.

Place a simple wooden fence around the tree. Inexpensive or scrap lumber will do. Snow fencing, although more expensive, is easy to install. The fence should enclose an area at least five feet out from the tree trunk. Erect the fence before the bulldozer arrives and leave it up until the last piece of equipment has left the area.

Marking

If erecting a barrier around the trees is impractical, marking the trees may help save them from damage, if equipment operators are forewarned and reliable. A band of bright colored cloth, ribbon, or tape may be used to identify trees to be protected. The band should be placed around the trunk high enough to be seen from a distance and from all angles. It is important that all people involved be informed of the meaning of the marking.



Grade Changes

Filling

Tree roots need air water and minerals to survive. Few trees can survive with more than six inches of earth fill over the roots. The tree roots are literally suffocated with more earth fill than this coarser the fill material, the better the chance for survival.

Construction of a dry well around the tree trunk will provide some air circulation for the trees. Installation of a drain system in conjunction with the dry well is even better. Four inch drain pipe is placed in a spoke-like fashion to drain water away from the tree before filling takes place.

The dry well may be built of stones, brick, tile, concrete blocks or other material. It should be built at least 12 to 18 inches away from the trunk of a large, slow-growing tree and up to 36 inches for younger fast-growing trees.

Lowering

Lowering the natural ground level can seriously damage trees and shrubs. Most of the plant roots are in the upper 12 inches of the soil and cuts of only 2-3 inches can cause serious injury. To protect the roots it may be necessary to terrace the immediate area around the plants to be saved. If roots are exposed, construction of retaining walls may be needed to keep the soil in place. Plants can also be preserved by leaving them on an undisturbed, gently sloping mound. To increase the chances for survival, it is best to limit grade changes and other soil disturbances to areas outside the dripline of the plant.

Excavations

Protect trees and other plants when excavating for tile, water, and sewer lines. Where possible, the trenches should be routed around trees and large shrubs. When this is not possible, it is best to tunnel under them. This can be done with hand tools or with power augers.

If it is not possible to route the trench around plants to be saved, then the following should be observed:

- Cut as few roots as possible. When you have to cut - cut clean. Paint cut root ends with a wood dressing like asphalt base paint.
- Backfill the trench as soon as possible.
- Tunnel beneath root systems as close to the center of the main trunk as possible to preserve most of the important feeder roots.

Common Trouble Points

Some problems that can be encountered with trees are:

- Maple, Dogwood, Eastern hemlock, Eastern red cedar and Douglas fir do not readily adjust to changes in environment and special care should be taken to protect these trees.
- Maples, and willows have water-seeking roots. These can cause trouble in sewer lines and filter fields. On the other hand, they thrive in high moisture conditions that other trees would succumb to.
- Thinning operations can cause serious disease problems. Disease can become established through damaged limbs, trunks, roots, and freshly cut stumps. Diseased and weakened trees are also susceptible to insect attack.

Maintenance

Inspect flagged areas regularly to make sure flagging has not been removed. If tree roots have been exposed or injured, re-cover and/or seal them.

References

Washington State Department of Ecology, ***Stormwater Management Manual for the Puget Sound Basin***, Olympia, WA, February, 1992.

U.S. Department of Agriculture, Soil Conservation Service, Amherst, MA, ***Guidelines for Soil and Water Conservation in Urbanizing Areas of Massachusetts***, October, 1977.

Riprap

A permanent, erosion-resistant ground cover of large, loose, angular stone.

RIPRAPPED STREAMBANK

Purpose

- To protect slopes, streambanks, channels, or areas subject to erosion by wave action.
- Rock riprap protects soil from erosion due to concentrated runoff. It is used to stabilize slopes that are unstable due to seepage. It is also used to slow the velocity of concentrated runoff which in turn increases the potential for infiltration.

Where Practice Applies

- Cut or fill slopes subject to seepage or weathering, particularly where conditions prohibit establishment of vegetation,
- Channel side slopes and bottom,
- Inlets and outlets for culverts, bridges, slope drains, grade stabilization structures, and storm drains; where the velocity of flow from these structures exceeds the capacity of the downstream area to resist erosion.
- Stream banks and stream grades,
- Shorelines subject to wave action.

Advantages

- Riprap offers an easy-to-use method for decreasing water velocity and protecting slopes from erosion. It is simple to install and maintain.
- Riprap provides some water quality benefits by increasing roughness and decreasing the velocity of the flow, inducing settling.

Disadvantages/Problems

- Riprap is more expensive than vegetated slopes.
- There can be increased scour at the toe and ends of the riprap.
- Riprap does not provide the habitat enhancement that vegetative practices do.

Planning Considerations

Well graded riprap forms a dense, flexible, self-healing cover that will adapt well to uneven surfaces.

Care must be exercised in the design so that stones are of good quality, sized correctly, and placed to proper thickness.

Riprap should be placed on a proper filter material of sand, gravel, or fabric to prevent soil from “piping” through the stone.

Contact the local Conservation Commission regarding any stream crossing or other work conducted in a wetland resource area. The Massachusetts Wetland Protection Act requires that the proponent file a “Determination of Applicability” or “Notice of Intent.”

Rock riprap is used where erosion potential is often high. The rock should be placed as soon as possible after disturbing the site, before additional water is concentrated into the drainage system. Properly sized bedding or geotextile fabric is needed to prevent erosion or undermining of the natural underlying material.

Riprap is classified as either graded or uniform. A sample of graded riprap would contain a mixture of stones which vary in size from small to large. A sample of uniform riprap would contain stones which are all fairly close in size.

For most applications, graded riprap is preferred to uniform riprap. Graded riprap forms a flexible self-healing cover, while uniform riprap is more rigid and cannot withstand movement of the stones. Graded riprap is cheaper to install, requiring only that the stones be dumped so that they remain in a well-graded mass. Hand or mechanical placement of individual stones is limited to that necessary to achieve the proper thickness and line. Uniform riprap requires placement in a more or less uniform pattern, requiring more hand or mechanical labor.

Design Recommendations

As graded riprap consists of a variety of stone sizes, a method is needed to specify the size range of the mixture of stone. This is done by specifying a diameter of stone in mixture for which some percentage, by weight, will be smaller. For example, d 85 refers to a mixture of stones in which 85 percent of the stone by weight would be smaller than the diameter specified. Most designs are based on “d.” The design, therefore, is based on the median size of stone in the mixture.

A well graded mixture of rock sizes should be used for riprap rather than rocks of a uniform size. Rock riprap sizes are specified by either weight or diameter.

Stone should be hard, angular, weather-resistant; specific gravity at least 2.5.

Gradation: well-graded stone, 50% by weight larger than the specified “150” The largest stones should not exceed 1.5 times the “d5O” specified.

Stones should be shaped so that the least dimension of the stone fragment is not less than one-third of the greatest dimension of the fragment. Flat rocks should not be used for riprap.

Filter: heavy-duty filter fabric or aggregate layer should be used under all permanent riprap installations.

Thickness: 1.5 times the maximum stone diameter, minimum, or as specified in the plan.

Construction Recommendations

Subgrade for the filter material, geotextile fabric or riprap should be cleared and grubbed to remove all roots, vegetation, and debris and prepared to the lines and grades shown on the plans.

Excavate deep enough for both filter and riprap. Compact any fill material to the density of surrounding undisturbed soil.

Excavate a keyway in stable material at base of slope to reinforce the toe. Keyway depth should be 1.5 times the design thickness of riprap and should “extend a horizontal distance equal to the design thickness.

Rock and/or gravel used for filter and riprap shall conform to the specified gradation.

Voids in the rock riprap should be filled with spalls and smaller rocks.

Filter

Install synthetic filter fabric or a sand/gravel filter on subgrade.

Synthetic filter fabric

Place filter fabric on a smooth foundation. Overlap edges at least 12 inches, with anchor pins spaced every 3 ft along overlap. For large stones, a 4-inch layer of sand may be needed to protect filtercloth.

Geotextile fabrics should be protected from puncture or tearing during placement of the rock riprap by placing a cushion of sand and gravel over the fabric. Damaged areas in the fabric should be repaired by placing a piece of fabric over the damaged area or by complete replacement of the fabric. All overlaps required for repairs or joining two pieces of fabric should be a minimum of 12 inches.

Sand/gravel filter

Spread well-graded aggregate in a uniform layer to the required thickness (6 inches minimum). If two or more layers are specified, place the layer of smaller stones first and avoid mixing the layers.

Stone Placement

Place riprap immediately after installing filter.

Install riprap to full thickness in one operation. Do not dump through chutes or use any method that causes segregation of stone sizes. Avoid dislodging or damaging underlying filter material when placing stone.

If fabric is damaged, remove riprap and repair fabric by adding another layer, overlapping the damaged area by 12 inches.

Place smaller stones in voids to form a dense, uniform, well-graded mass. Selective loading at the quarry and some hand placement may be necessary to obtain an even distribution of stone sizes.

Blend the stone surface smoothly with the surrounding area allowing no protrusions or overfall.

Since riprap is used where erosion potential is high, construction must be sequenced so that the riprap is put in place with the minimum possible delay. Disturbance of areas where riprap is to be placed should be undertaken only when final preparation and placement of the riprap can follow immediately behind the initial disturbance.

Where riprap is used for outlet protection, the riprap should be placed before or in conjunction with the construction of the pipe or channel so that it is in place when the pipe or channel begins to operate.

Common Trouble Points

Excavation not deep enough

Riprap blocks channel, resulting in erosion along edges.

Slope too steep

Results in stone displacement. Do not use riprap as a retaining wall.

Foundation not properly smoothed for filter placement

Results in damage to filter.

Filter omitted or damaged

Results in piping or slumping.

Riprap not properly graded

Results in stone movement and erosion of foundation.

Foundation toe not properly reinforced
Results in undercut riprap slope or slumping.

Fill slopes not properly compacted before placing riprap
Results in stone displacement.

Maintenance

Riprap should be checked at least annually and after every major storm for displaced stones, slumping, and erosion at edges, especially downstream or downslope. If the riprap has been damaged, it should be repaired immediately before further damage can take place.

Woody vegetation should be removed from the rock riprap annually because tree roots will eventually dislodge the riprap.

If the riprap is on a channel bank, the stream should be kept clear of obstructions such as fallen trees, debris, and sediment bars that may change flow patterns which could damage or displace the riprap.

References

Massachusetts Department of Environmental Protection, Office of Watershed Management, Nonpoint Source Program, Massachusetts ***Nonpoint Source Management Manual***, Boston, Massachusetts, June, 1993.

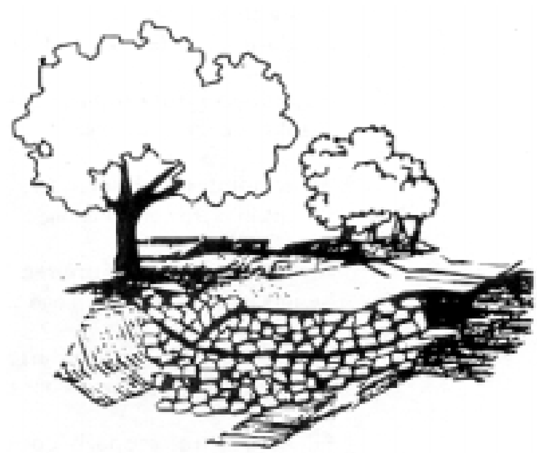
Minnick, E. L., and H. T. Marshall, ***Stormwater Management and Erosion Control for Urban and Developing Areas in New Hampshire*** , Rockingham County Conservation District, August 1992.

North Carolina Department of Environment, Health, and Natural Resources, ***Erosion and Sediment Control Field Manual,*** Raleigh, NC, February 1991.

Washington State Department of Ecology, ***Stormwater Management Manual for the Puget Sound Basin***, Olympia, WA, February, 1992.

Rock Dam

A rock embankment constructed across a drainageway or other suitable location to create a temporary basin for collecting sediment.



Purpose

To trap sediment on the construction site and prevent off-site sedimentation. Useful where earth fill material is not readily available.

Where Practice Applies

Where a temporary measure is needed to retain sediment from a construction area - but not in a natural stream.

Design Criteria

Drainage area: limited to 50 acres.
Design life: limited to 3 years.
Sediment storage: 1800 cubic feet per acre disturbed, as a minimum. Measured one foot below spillway crest.
Dam crest height: limited to 8 feet.
Basin area and shape: The largest surface area gives the greatest trapping efficiency. Basin length-to-width ratio should be 2:1 minimum.
Spillway capacity: 10-year peak runoff, at maximum flow depth of one foot and minimum freeboard of one foot. Entire length of dam between rock abutments may serve as spillway.
Rock embankment:

Top width 5 ft minimum

Side slopes Upstream, 2:1 or flatter; Downstream, 3:1 or flatter

Earth abutments Smooth, stable slopes, 2:1 or flatter.

Rock abutments Must protect earth abutments and extend along downstream face to toe of dam. Abutments must be at least one foot higher than the spillway face at all points.

Height	2 ft minimum above spillway crest
Width	2 ft thick, minimum
Side slopes	2:1 or flatter

Outlet protection: Rock apron, 1.5 ft thick, minimum, zero grade, length equal to height of dam or extended to stable grade, whichever is greater.
Rock material: Well-graded, hard, angular, weather-resistant stone with a "d50" of 9 inches minimum.
Protection from piping: Extra-strength filter fabric covering entire foundation including earth abutments and apron.
Basin dewatering: Through one-foot thick minimum layer of ½- to ¾-inch aggregate on upstream face of dam.

Installation

Divert runoff from undisturbed areas away from the basin. Delay clearing pond area until dam is in place.

Excavate foundation for apron and use it as a temporary sediment basin during construction of dam.

Clear and grub area under darn, removing all root mat and other objectionable material. Grade earth abutments no steeper than 1:1. Dispose of material in approved location.

If cutoff trench is required, excavate at center line of dam, extending all the way up earth abutments.

Protection from Piping

The entire foundation including both earth abutments must be covered by filter fabric. Overlap one foot at all joints, upstream strip over downstream strip.

Smooth the foundation area before placing filter fabric. Be careful placing rock on fabric. It may be helpful to place a 4-inch layer of sand over fabric before placing rock.

Embankment and pool

Construct embankment to dimensions shown on plans. Use well-graded, hard, angular, weather-resistant rock. Rock abutments must be at least 2 feet higher than the spillway crest and at least 1 foot higher than the downstream face of dam at all points.

Divert sediment-laden flow to upper end of basin.

Set marker stake to indicate clean out elevation where sediment pool is 50% full.

Establish vegetation to stabilize all disturbed areas except the lower one-half of sediment pool as shown in the plan.

Safety

Sediment basins that impound water are hazardous. Basin should be dewatered between storms. Avoid steep side slopes. Fences with warning signs may be necessary if trespassing is likely. State and local requirements must be followed.

Common Trouble Points

Failure from piping along abutments
Filter material not properly installed, or earth abutments too steep.

Stone displaced from face of dam
Stone size too small and/or face too steep.

Erosion below dam
Apron not extended to stable grade.

Erosion of abutments during spillway flow
Rock abutment height inadequate.

Sediment carried through spillway
Drainage area too large. Divert runoff from undisturbed area away from basin.

Sediment loss through dam
Inadequate layer of aggregate on inside face or aggregate too coarse to restrict flow through dam.

Maintenance

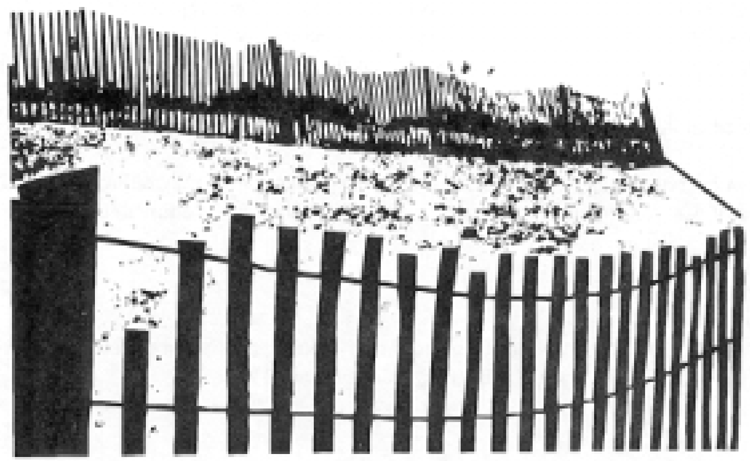
- Inspect rock dam and pool after each rainfall event.
- Remove sediment when it accumulates to one-half design volume (marked by stakes).
- Check structure and abutments for erosion, piping, or rock displacement. Repair immediately.
- Replace aggregate on inside face of structure when sediment pool does not drain between storms.
- Add fine gravel to upstream face of dam if sediment pool drains too rapidly (less than 6 hours) following a storm.
- Remove rock dam after the contributing drainage area has been permanently stabilized, inspected, and approved. Remove all water and sediment prior to removing dam. Dispose of waste materials in designated disposal areas. Smooth site to blend with surrounding area and stabilize according to vegetation plan.

References

North Carolina Department of Environment, Health, and Natural Resources, ***Erosion and Sediment Control Field Manual***, Raleigh, NC, February 1991.

Massachusetts Department of Environmental Protection, Office of Watershed Management, Nonpoint Source Program, ***Massachusetts Nonpoint Source Management Manual, Boston***, Massachusetts, June, 1993.

Sand Dune and Sandblow Stabilization



Planning Considerations

Active sand areas may be stabilized by establishing temporary control measures, followed by tree or shrub planting within five years. In situations where trees or shrubs are not desired or practical, such as the seaface of a beach frontal dune, American beachgrass may be maintained as a long-term means of stabilization.

Methods of Stabilization

Mechanical - This is usually done with brush matting or with sand fencing. It is usually limited to small areas where beachgrass is not available for planting, or where immediate stabilization is desired.

Place brush matting (preferably coniferous) with butts to windward. Start placing on leeward side, working towards windward side. Overlap butts with tops to provide a shingling effect. Sand fencing placed at right angles to the prevailing wind will also give temporary stabilization but is expensive and more prone to vandalism.

Beachgrass - Beachgrass may be a temporary or long-term measure. American beachgrass is planted in culms. Culms should consist of two or more healthy stems, 2 to 3 feet tall. The ideal time to plant dormant beachgrass culms is in early spring, March 15 to May 1. Culms should be planted 8 to 9 inches deep. Culms may be dug anytime during the planting season. The stems should be cut back to 12 to 15 inches before or after digging. They may be stored by heeling-in, or storing at 28 to 32 degrees F.

Culm plantings should be planted at 18 inch spacings, with center staggered in alternate rows. Five hundred to 1,000 pounds per acre of 10-5-5, or equivalent analysis, should be applied soon after planting, or in the case of a fall planting, the fertilizer should be applied early the following spring.

An alternative, less expensive method, is to plant the beachgrass in bands. These bands should be spaced 20 to 40 feet apart. The bands should consist of at least 2 rows spaced approximately 18 inches apart, with culms approximately 18 inches apart in the rows and centers staggered in alternate rows. The closer band spacing should be used on the windward side. Fertilizer should be applied to the planted bands as indicated above.

When beachgass is to be used for long-term protection, it may be maintained by annual applications of 300-500 pounds per acre of a 10-5-5 fertilizer or its equivalent.

References

North Carolina Department of Environment, Health, and Natural Resources, ***Erosion and Sediment Control Field Manual***, Raleigh, NC, February 1991.

Tree Plantings for Enduring Cover Species

Inland Areas	**Coastal Areas**
Eastern red cedar*	Pitch pine

Density and Arrangement:
400-1,000 plants per acre uniformly spaced. Trees should be planted where existing vegetation is least competitive.

Shrub Plantings for Enduring Cover Species

Inland Areas	**Coastal Areas**
Bayberry	Beach plum
Eastern red cedar*	Bayberry
Rugosa rose	Rugosa rose

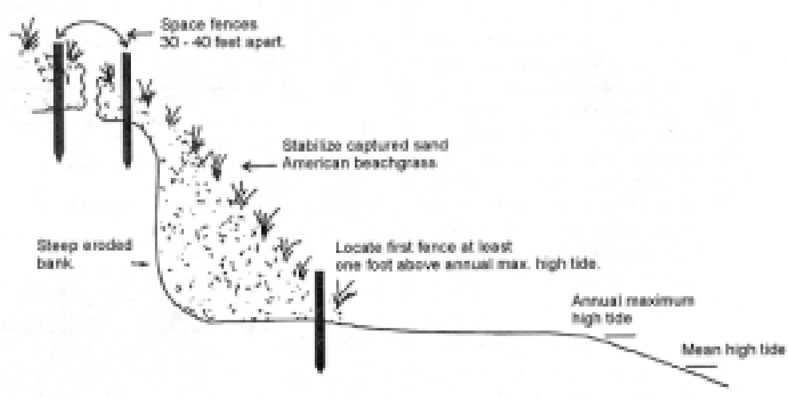
Density and Arrangement
Plant in rows or uniform spacing with 4 to 6 feet between plants.

**Caution to users who may be near orchards: Eastern red cedar is an alternate host to apple rust.*

Sand Fence

An artificial barrier of evenly spaced wooden slats or synthetic fabric erected perpendicular to the prevailing wind and supported by posts.

Sand fences are usually made commercially of light wooden slats wired together with spaces between the slats. The distance between slats is approximately equal to the slat width (about 1 ½ inches). Synthetic fencing fabric is available for this use. The fences are erected 2 to 4 feet high in parallel rows spaced 30 to 40 feet apart over the area to be protected. Fences are supported by wooden or metal posts.



Purpose

To reduce wind velocity at the ground surface and trap blowing sand. Typically used for rebuilding frontal dunes along coastal areas.

Where Practice Applies

- Across open bare, sandy soil areas subject to frequent winds, where the trapping of blowing sand is desired.
- Wind fences are used primarily to build frontal ocean dunes (to control erosion from wave overwash and flooding).
- Sand fences can also be used to prevent sand from blowing off disturbed areas onto roads or adjacent property.

Planning Considerations

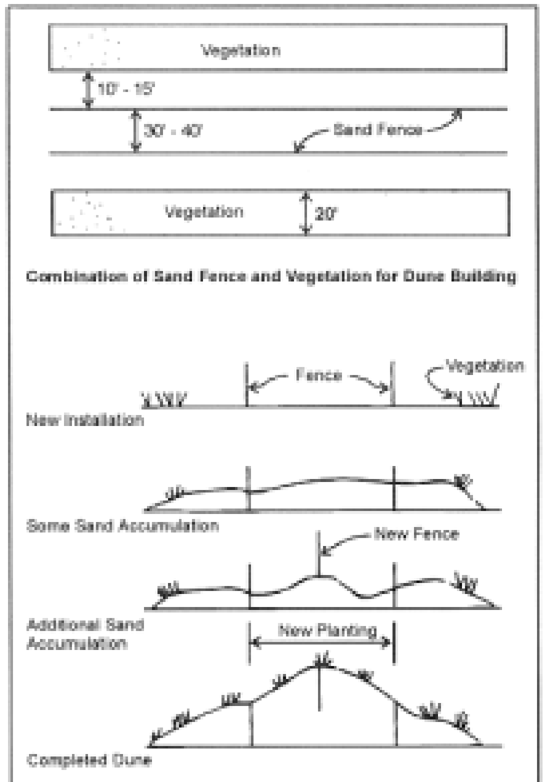
When wind fences are approximately two-thirds full, another series of fences is erected. In this manner, dunes can be built 2 to 6 feet high or more during a single season. When the dune has reached the approximate height of other mature dunes or when the building process slows significantly, stabilize with appropriate vegetation.

Installation

Install sand fences in spring or early summer and seed selected permanent vegetation in the fall or the following spring.

Erect a windward fence parallel to existing dune (generally perpendicular to the prevailing onshore wind), at least one foot above the maximum annual high water elevation. Locate a second fence generally parallel to the first at the top edge of the eroded dune bank. Space additional parallel fences 30 - 40 feet apart as needed over the area to be built up).

A second set of fences may be erected perpendicular to the first to protect captured dune sand from cross winds. Space perpendicular fences a greater distance apart (50-75 feet).



Typical Cross-sections created by a combination of Sand Fence and Vegetation.

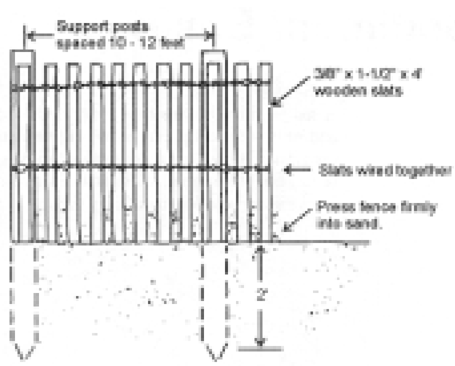
Support fencing material with 2 x 4-inch or 3-inch round posts, 6 feet long minimum, driven firmly into the ground at least 2 feet and spaced approximately 12 feet apart. Alter spacing so that posts are placed at all low points. Secure fencing to windward side of posts by tying or nailing. Press bottom of fencing material firmly into the ground at all points.

Raising the Dune

When the fence system is approximately two-thirds filled with sand, erect another series of fences until desired dune height is reached.

Final Stabilization

When the dune-building process slows significantly, the dune must be permanently stabilized. Planting should begin in November and be completed the following spring even if the dune has not reached the desired height. Vegetation hastens the building process. Maintain fences until vegetation is well established.



Common Trouble Points

Bottom fence located too low
Fence washes out.

Fences not maintained long enough
Some seasons provide little opportunity for dune building and fences may have to be maintained for longer periods.

Dune not adequately stabilized with permanent vegetation
Dune is subject to erosion during storms, even with sand fences in place.

Fencing material placed on leeward side of posts or not adequately secured
Sections of fence collapse.

Posts not driven deep enough
Fence collapses.

Fence system located too near the ocean
Not enough sand source for dune building.

Maintenance

Inspect sand fences periodically, and immediately following storms. Repair damaged sections of fence promptly.

Maintain fences until vegetation is well established.

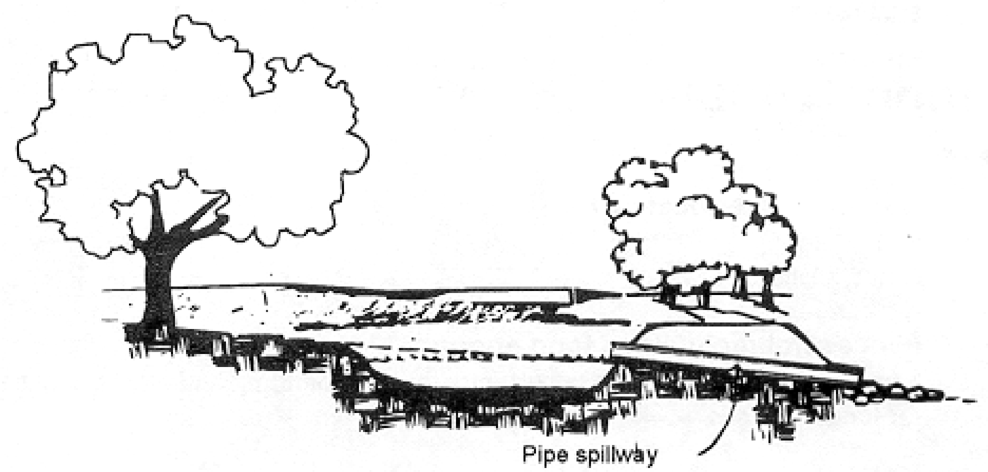
References

Massachusetts Department of Environmental Protection, Office of Watershed Management, Nonpoint Source Program, Massachusetts ***Nonpoint Source Management Manual Boston***, Massachusetts, June, 1993.

North Carolina Department of Environment, Health, and Natural Resources, ***Erosion and Sediment Control Field Manual***, Raleigh, NC, February 1991.

Sediment Basin

A sediment basin is a settling pond with a controlled storm water release structure used to collect and store sediment produced by construction activities. A sediment basin can be constructed by excavation or by placing an earthen embankment across a low area or drainage swale. Sediment basins can be designed to maintain a permanent pool or to drain completely dry. The basin detains sediment-laden runoff long enough to allow most of the sediment to settle out.



Purpose

- To collect and store sediment from sites cleared and/or graded during construction or for extended periods of time before reestablishment of permanent vegetation or construction of structures.
- To retain sediment on the construction site and prevent off-site sedimentation.

Where Practice Applies

Sediment basins are needed where other erosion control measures are not adequate to prevent offsite sedimentation.

A sediment basin should be used only where is sufficient space and appropriate topography. The basin should be made large enough to handle the maximum expected amount of site drainage.

Fencing around the basin may be necessary for safety or vandalism reasons.

A sediment basin used in combination with other control measures, such as seeding or mulching, is especially effective for removing sediments.

Dam Safety Regulations must be followed where applicable.

Advantages

Protects downstream areas from clogging or damage due to sediment deposits generated during construction activities.

Because of additional detention time, sediment ponds may be capable of trapping smaller-sized sediment particles than other practices. They are most effective, however, when used in conjunction with other practices such as seeding or mulching.

Disadvantages/Problems

Ponds may become an “attractive nuisance” and a safety hazard.

Sediment ponds are only effective in removing sediment down to about the medium silt size fraction. Sediment-laden runoff with smaller-size fractions (fine silt and clay) will pass through untreated; emphasizing the need control erosion to the maximum extent first.

Planning Considerations

Sediment basins are usually constructed by building a low earthen dam across a drainageway to form a temporary sediment storage pool. A properly designed spillway outlet with adequate freeboard is essential.

A sediment basin may be created by excavation, construction of a compacted embankment, or a combination of both. It may have one or more inflow points carrying polluted runoff.

Basins should be installed before clearing and grading begin.

To improve trap efficiency the basin should have the maximum surface area possible, and sediment should enter the basin as far from the outlet as possible.

Sediment basin life should be limited to 3 years, unless it is designed as a permanent structure.

Effectiveness

Sediment basins are at best only 70-80 percent effective in trapping sediment which flows into them. Therefore, they should be used in conjunction with erosion control practices such as temporary seeding, mulching, diversion dikes, etc. to reduce the amount of sediment flowing into the basin. Sediment basins are most effective when designed with a series of chambers.

Location

Locate sediment basins only in upland areas, not wetlands.

Ensure that basin location provides a convenient concentration point for sediment laden flows from the area served.

To improve the effectiveness of the basin, it should be located so as to intercept the largest possible amount of runoff from the disturbed area. The best locations are generally on relatively flat terrain downstream from disturbed areas.

Drainage into the basin can be improved by the use of diversion dikes and ditches.

The basin must not be located in a stream but should be located to trap sediment-laden runoff before it enters the stream.

The basin should not be located where its failure would result in the loss of life or interruption of the use or service of public utilities or roads.

Diversions

Divert sediment-laden water to upper end of sediment pool to improve trap effectiveness. Bring all water into the basin at low velocity to prevent erosion.

Divert runoff from undisturbed areas away from basin.

Multiple Use

Sediment basins may be designed as permanent structures to remain in place after construction is completed for use as stormwater detention ponds. Sediment must be removed from the pond when construction is complete to prepare the pond for permanent use.

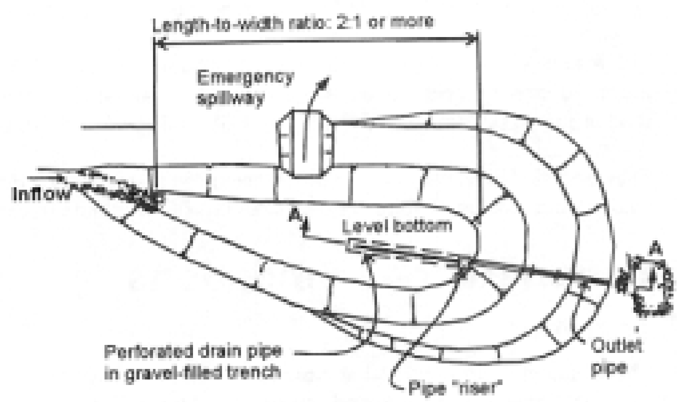
Design Recommendations

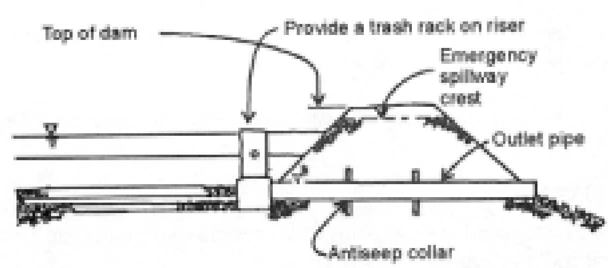
Drainage area - Not more than 100 acres.
Sediment storage - The sediment basin should have a minimum volume based on ½ inch of storage for each acre of drainage area. This volume equates to 1800 cubic feet of storage or 67 cubic yards for each acre of drainage area.
Trap efficiency - Length-to-width ratio should be 2:1 or greater; divert inflow to upper end of basin to avoid short-circuiting flow. Length is defined as the average distance from the inlet to the outlet of the trap. Baffles to spread the flow throughout the basin should be included.
Dewatering - Perforate riser and cover holes with gravel.
Total spillway capacity -10-year peak flow with 1 foot freeboard.

Principal Spillway

Riser and barrel - Usually vertical pipe riser with horizontal pipe barrel; must withstand the maximum external loading without yielding, buckling, or cracking. Pipe connections must be watertight.
Capacity Minimum of 0.2 cfs/acre of drainage.
Barrel diameter - 8-inch corrugated pipe minimum, or 6-inch smooth-wall pipe minimum.
Riser cross-sectional area - 1.5 x barrel area, minimum.
Dewatering - Perforate lower half of riser in each outside valley with ½-inch holes spaced approximately 3 inches. If corrugated pipe is used, locate holes along each outside valley. Cover with 2 ft of ½- to ¾-inch aggregate.
Crest of principal spillway - One foot minimum below elevation of emergency spillway crest.

Seepage prevention - At least one watertight antiseep collar with a minimum projection of 2 feet is required around barrel of pipes 8 inches in diameter or larger. The antiseep collar(s) shall increase by 15 percent the seepage path along the pipe from the riser to downstream toe of dam.
Anti-flotation block - Riser must be held in place with an anchor having buoyant weight greater than 1.1 times the weight of water displaced by riser and any exposed portion of barrel.
Trash guard - Required at top of riser.
Outlet - Must be stable for design pipe discharge. Install riprap outlet apron unless foundation is rock.





Section A-A

Emergency Spillway

Capacity - 10-year peak flow, minus flow in principal spillway.
Location - Construct in undisturbed soil - not fill.
Cross section - Trapezoidal with side slopes 3:1 or flatter.
Control section - Level and straight, at least 20 feet long. Outlet section must be straight.
Embankment - Top width 8 feet minimum for dam height less than 10 feet. 10 feet minimum for dam height of 10 to 15 feet.
Side slopes - 2.5:1 or flatter.
Settlement allowance - 10% of design height.

Cutoff trench - Required tinder centerline of dam, depth 2 feet minimum into undisturbed firm mineral soil. Extend trench up each abutment to elevation of emergency spillway crest. The bottom width should be wide enough to permit operation of excavation and compaction equipment, but not less than 4 feet wide. Side slopes should be no steeper than 1:1.

Fill material - The fill material should be clean mineral soil free of roots, woody vegetation, oversized stones, rocks, or other objectionable material. Relatively pervious materials such as sand or gravel (Unified Soil Classification GW, GP, SW, and SP) should not be used in the fill.

Freeboard - “Freeboard” is the difference between the design flow elevation in the emergency spillway and the top elevation of the embankment. Minimum freeboard should be one foot.

Construction Recommendations

Site Preparation

The sediment basin should be as close to the sediment source as site conditions allow considering soils, pool area, dam length, and spillway conditions. Delay clearing pool until dam is complete to reduce erosion and off-site sedimentation.

Clear, grub, and strip dam location. Excavate area for the outlet apron.

Remove surface soil containing high amounts of organic matter and stockpile for later use. Clear sediment pool to facilitate sediment cleanout.

Dispose of trees, limbs, logs, and other debris in designated disposal areas.

Cutoff Trench

Excavate cutoff trench along dam centerline extending up both abutments to elevation of principal spillway crest.

Cut trench into stable soil material, at least 2 ft wide and at least 2 ft deep with side slopes 1H: 1V or flatter.

Backfill with clayey soil if available. Compaction requirements: same as those for embankment. The trench should be de-watered during the backfilling and compaction operations.

Principal Spillway

Use only approved watertight assemblies as shown in the plans for all pipe connections. Rod and lug connector bands with gaskets are recommended for corrugated pipe. Do not use dimple (universal) connector bands. Connection between pipe and anti-seep collar must be watertight.

Place barrel and riser on firm, even foundation. Install anti-seep collar(s) slightly downstream of dam centerline.

Place moist, clayey, workable soil around pipe and anti-seep collars. Do not use pervious material such as sand, gravel, or silt. Compact 4-inch layers of soil, by hand, under and around pipe and collars to at least the density of foundation soil. Avoid raising pipe from firm contact with foundation while compacting material under pipe haunches.

Cover pipe to a depth of 2 feet minimum of hand-compacted backfill before crossing it with construction equipment.

Anchor riser in place with concrete to prevent flotation. Embed riser at least 6 inches into concrete.

Install trash guard with bars spaced 2-3 inches apart.

Install riprap apron at pipe outlet, width 5 ft minimum. Extend apron to stable grade (length 10 ft minimum). Use well-graded stone with “d50” of 9 inches minimum.

Embankment

Scarify base of dam before placing fill.

Fill material should be placed in 6- to 8-inch continuous layers over the entire length of the fill and compacted. Save the least permeable soil for center portion of dam. Place the most permeable soil in downstream toe.

Compaction may be obtained by routing the hauling equipment over the fill so that the entire surface of each layer of the fill is traversed by at least one wheel or tread track of the equipment. If compaction is obtained with hauling equipment, an elevation 10 percent higher than the design height is required to allow for settlement. If compactors are used for compaction, the overbuild may be reduced to not less than 5 percent.

Fill material must contain sufficient moisture that it can be formed by hand into a ball without crumbling. If water can be squeezed out of the ball, it is too wet for proper compaction.

Construct dam to lines and grades shown in plan. Side slopes must be 2.5:1 or flatter.

Compact fill material in 6- to 8-inch continuous layers over length of dam. Compaction may be obtained by routing construction equipment over fill so that the entire surface of each layer is traversed by at least one wheel of compacting equipment. Protect spillway barrel with 2 ft of hand-compacted fill before traversing with equipment

Construct embankment 10% higher than design height to allow for settlement.

Emergency Spillway

Cut emergency spillway in undisturbed soil to lines and grade shown in the approved plan. Side slopes must be 3:1 or flatter.

Control section must be level and straight, 20 ft long minimum. Exit section must be straight.

Vegetate spillway as soon as grading is complete, following all requirements in vegetation plan. Anchor mulch in spillway with netting.

Install paving material to finished grade if spillway is not to be vegetated.

Cleanout

Place reference stake at sediment cleanout elevation (50% of design volume).

Erosion Control

Minimize the area disturbed and time of exposure.

Excavate the outlet apron area first, to use as a sediment trap during construction of dam.

Use temporary diversions to prevent surface water from running onto disturbed areas.

Construct embankment before clearing the sediment pool.

Stabilize all disturbed areas except lower one-half of sediment basin immediately after construction.

Safety

Sediment basins should be installed only on sites where failure of the structure would not result in loss of life, damage to homes or buildings, or interruption of use or service of public roads or utilities.

Sediment basins are attractive to children and can be very dangerous.

Keep sediment pool dewatered between storms.

Construct side slopes 2:1 or flatter in pool area.

Fence area if trespassing is likely. Post signs warning the public of hazards of soft sediment and floodwater.

Follow all state and local requirements.

Common Trouble Points

Piping failure along conduit

Due to lack of proper compaction, omission of anti-seep collar, or leaking pipe joints.

Erosion of spillway or embankment slopes

Due to inadequate vegetation or improper grading and sloping.

Slumping and/or settling of embankment

Due to inadequate compaction and/or use of poor-quality fill material.

Slumping failure

Due to steep side slopes.

Erosion and caving below pipe

Due to inadequate outlet protection.

Basin not located properly for access

Makes maintenance difficult and costly.

Sediment not properly removed

Leaves inadequate storage capacity.

Lack of anti-flotation pipe

Damage from uplift.

Lack of trash rack

Barrel and riser blocked with debris.

Elevations of principal spillway and emergency spillway too high relative to top of dam
Potential failure from overtopping.

Maintenance

Sediment basins should be readily accessible for maintenance and sediment removal. The sediment basin should remain in operation and be properly maintained until the site area is permanently stabilized by vegetation and/or when permanent structures are in place.

Inspect sediment basins after each significant rainfall.

Remove and properly dispose of sediment when it accumulates to one-half design volume (level marked by reference stake). The effectiveness of a sediment pond is based less on its size than on regular sediment removal.

Check embankment, emergency spillway, and outlet for erosion damage.

Check embankment for: settlement, seepage, or slumping along the toe or around pipe. Look for signs of piping. Repair immediately. Remove trash and other debris from principal spillway, emergency spillway, and pool area.

Clean or replace gravel when sediment pool does not drain properly.

Remove basin after drainage area has been permanently stabilized, inspected, and approved. Before removing dam, drain water and remove sediment; place waste material in designated disposal areas. Smooth site to blend with surrounding area and stabilize.

References

Massachusetts Department of Environmental Protection, Office of Watershed Management, Nonpoint Source Program, ***Massachusetts Nonpoint Source Management Manual***, Boston, Massachusetts, June, 1993.

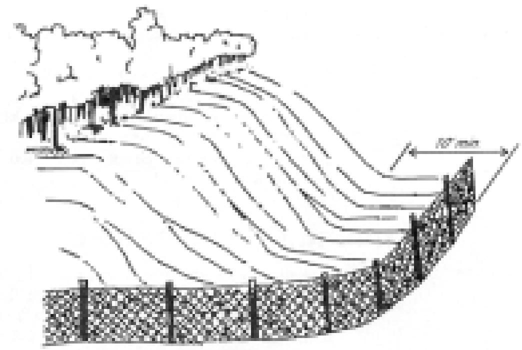
Minnick, E. L., and H. T. Marshall, ***Stormwater Management and Erosion Control for Urban and Developing Areas in New Hampshire***, Rockingham County Conservation District, August 1992.

North Carolina Department of Environment, Health, and Natural Resources, ***Erosion and Sediment Control Field Manual***, Raleigh, NC, February 1991.

U.S. Environmental Protection Agency, ***Storm Water Management For Construction Activities***, EPA-832-R- 92-005, Washington, DC, September, 1992.

Washington State Department of Ecology, ***Stormwater Management Manual for the Puget Sound Basin***, Olympia, WA, February, 1992.

Sediment Fence



A temporary sediment barrier consisting of a filter fabric stretched across and attached to supporting posts and entrenched. The sediment fence is constructed of stakes and synthetic filter fabric with a rigid wire fence backing where necessary for support.

Sediment fence can be purchased with pockets presewn to accept use of steel fence posts.

Purpose

A sediment fence intercepts and detains small amounts of sediment from disturbed areas during construction operations and reduces runoff velocity down a slope.

Sediment fences may also be used to catch wind-blown sand and to create an anchor for sand dune creation.

Where Practice Applies

- Below small disturbed areas of less than ¼ acre per 100 feet of fence, where runoff may occur in the form of sheet and rill erosion.
- Where there is no concentration of water in a channel or other drainageway above the fence, and drainage area is usually not more than 1-½ acres.
- Where runoff can be stored behind the sediment fence without damaging the fence, or the submerged area behind the fence.
- Where erosion would occur only in the form of sheet erosion.
- Do not install sediment fences across streams, ditches, or waterways.

Advantages

- Removes sediments and prevents downstream damage from sediment deposits
- Reduces the speed of runoff flow
- Minimal clearing and grubbing required for installation
- Sediment fences trap a much higher percentage of suspended sediments than straw bales.

Disadvantages/Problems

Sediment fences are not practical where large flows of water are involved. Their use is recommended only for small drainage areas, and flow rates of less than 0.5 cfs.

Flow should not be concentrated; it should be spread out over many linear feet of sediment fence.

Problems may arise from incorrect selection of filter fabric or from improper installation.

Sediment fences are not an adequate method of runoff control for anything deeper than sheet or overland flow.

Planning Considerations

Sediment fences should be located where they will trap sediment; that is, where there will be contributing runoff. A sediment fence, located along the top of a ridge serves no useful purpose, except as it may be used to mark limits of a construction area. A sediment fence located at the upper end of a drainage area performs no sediment-collecting function.

Sediment fences are preferable to straw barriers in many cases. While the failure rate is lower than that of straw barriers there are, however, many cases in which sediment fences have been improperly installed.

Sediment fences have a low permeability to enhance sediment trapping. This will create ponding behind the fence, so they should not be located where ponding will cause property damage or a safety hazard.

The sedimentation pool behind the fence is very effective and may reduce the need for sediment basins and traps.

Sediment fences may be designed to store all the runoff from the design storm or located to allow bypass flow when the temporary sediment pool reaches a predetermined level.

The drainage area must be restricted and the fence located so that water depth does not exceed 1.5 feet at any point.

The expected life of a sediment fence is generally six months.

To use sediment fences effectively, provide access to the locations where sediment accumulates and provide reinforced, stabilized outlets for emergency overflow.

Sediment fence is most effective when used in conjunction with other practices such as perimeter dikes or diversions.

Allow for safe bypass of storm flow to prevent overtopping failure of fence.

Do not install sediment fence across intermittent or permanent streams, channels, or any location where concentrated flow is anticipated.

It is not necessary to use straw or hay bales together with a sediment fence.

Design Recommendations

Depth of impounded water should not exceed 1.5 feet at any point along the fence.

Drainage area

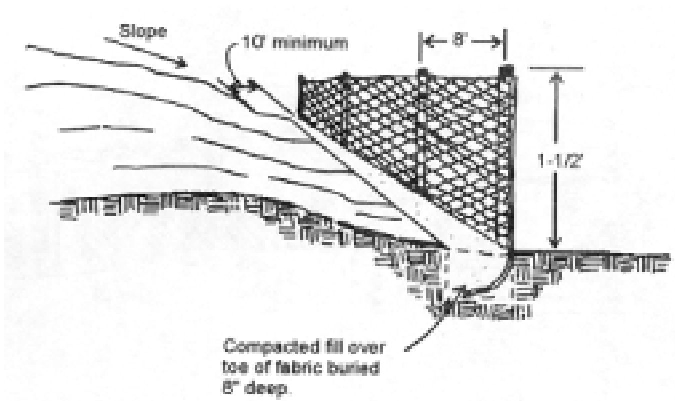
Limited to ¼ acre per 100 ft of fence, and no more than 1.5 acres in total; or in combination with a sediment basin on a larger site. Area is further restricted by slope steepness as shown in the following table.

Land Slope (%)	Maximum Slope Distance Above Fence (feet)
2	250
5	180
10	100
20	50
30	30

Location

Locate the fence at least 10 feet from the toe of steep slopes to provide sediment storage and access for cleanout.

The fence line should be nearly level through most of its length to impound a broad, temporary pool. The last 10 to 20 feet at each end of the fence should be swung slightly uphill (approximately 0.5 feet in elevation) to provide stroage capacity.



Stabilized outlets are required for bypass flow, unless the fence is designed to retain all runoff from the 10-year storm.

The fence line may run slightly off level (grade less than 1%) if it terminates in a level section with a stabilized outlet, diversion, basin, or sediment trap. There must be no gullying along the fence or at the ends. A sediment fence should not be used as a diversion.

Materials and Use

Filter Fabric

The filter fabric used in a sediment fence must have sufficient strength to withstand various stress conditions. It also must have the ability to allow passage of water while retaining soil particles. Filter fabric for a sediment fence is available commercially.

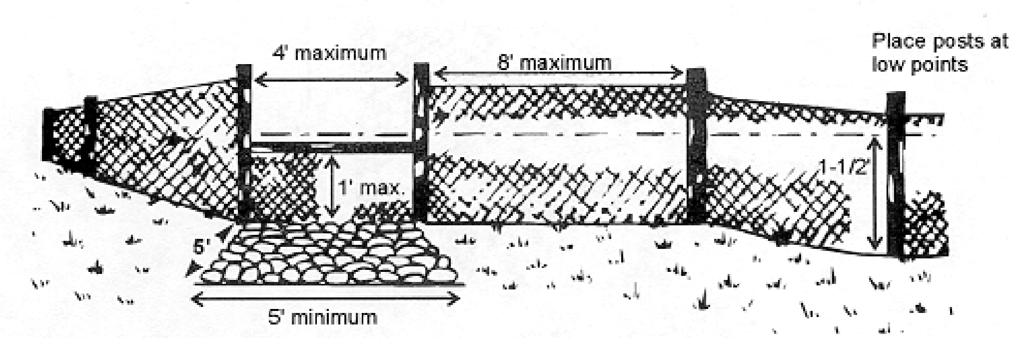
Support posts
Four-inch diameter pine, 1.33 lb./linear ft. steel, or sound quality hardwood with a minimum cross sectional area of 3.0 square inches. Steel posts should have projections for fastening fabric.
Drive posts securely, at least 16 inches into the ground, on the downslope side of the trench. Space posts a maximum of 8 feet if fence is supported by wire, 6 feet if extra-strength fabric is used without support wire. Adjust spacing to place posts at low points along the fenceline.
Support wire
Wire fence (14 gauge with 6-inch mesh) is required to support standard-strength fabric.

Reinforced, stabilized outlets

Any outlet where storm flow bypass occurs must be stabilized against erosion.

Set outlet elevation so that water depth cannot exceed 1.5 feet at the lowest point along the fenceline.

Set fabric height at 1 foot maximum between support posts spaced no more than 4 feet apart. Install a horizontal brace between the support posts to serve as an overflow weir and to support top of fabric. Provide a riprap splash pad a minimum 5 feet wide, 1 foot deep, and 5 feet long on level grade. The finished surface of the riprap should blend with surrounding area, allowing no overfall. The area around the pad must be stable.



Construction Recommendations

Dig a trench approximately 8 inches deep and 4 inches wide, or a V-trench; along the line of the fence, upslope side.

Fasten support wire fence securely to the upslope side of fence posts with wire ties or staples. Wire should extend 6 inches into the trench.

Attach continuous length of fabric to upslope side of fence posts. Avoid joints, particularly at low points in the fence line. Where joints are necessary, fasten fabric securely to support posts and overlap to the next post.

Place the bottom one foot of fabric in the trench. Backfill with compacted earth or gravel.

Filter cloth shall be fastened securely to the woven wire fence with ties spaced every 24 inches at the top, mid-section, and bottom.

To reduce maintenance, a shallow sediment storage area may be excavated on the upslope side of fence where sedimentation is expected.

Provide good access to deposition areas for cleanout and maintenance.

Sediment fences should be removed when they have served their useful purpose, but not before the upslope area has been permanently stabilized. Retained sediment must be removed and properly disposed of, or mulched and seeded.

Common Trouble Points

Fence sags or collapses:

- Drainage area too large,
- Too much sediment accumulation allowed before cleanout,
- Approach too steep, or
- Fence not adequately supported.

Fence fails from undercutting:

- Bottom of fence not buried at least 8 inches at all points,
- Trench not backfilled with compacted earth or gravel,
- Fence installed on excessive slope, or
- Fence located across drainage way.

Fence is overtopped:

- Storage capacity inadequate, or
- No provision made for safe bypass of storm flow, or
- Fence located across drainage way.

Erosion occurs around end of fence:

- Fence terminates at elevation below the top of the temporary pool.
- Fence terminates at unstabilized area, or
- Fence located on excessive slope.

Maintenance

A sediment fence requires a great deal of maintenance. Silt fences should be inspected immediately after each rainfall and at least daily during prolonged rainfall. Repair as necessary.

Remove sediment deposits promptly to provide adequate storage volume for the next rain and to reduce pressure on fence. Take care to avoid undermining fence during cleanout.

If the fabric tears, decomposes, or in any way becomes ineffective, replace it immediately.

Replace burlap used in sediment fences after no more than 60 days.

Remove all fencing materials after the contributing drainage area has been properly stabilized. Sediment deposits remaining after the fabric has been removed should be graded to conform with the existing topography and vegetated.

References

Massachusetts Department of Environmental Protection, Office of Watershed Management, Nonpoint Source Program, Massachusetts ***Nonpoint Source Management Manual***, Boston, Massachusetts, June, 1993.

Minnick, E. L., and H. T. Marshall, S***tormwater Management and Erosion Control for Urban and Developing Areas in New Hampshire***, Rockingham County Conservation District, August 1992.

North Carolina Department of Environment, Health, and Natural Resources, ***Erosion and Sediment Control Field Manua***l, Raleigh, NC, February 1991.

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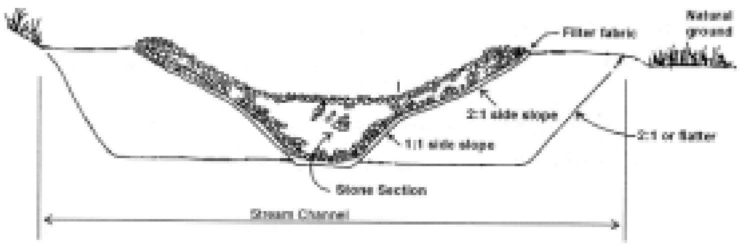
U. S. Environmental Protection Agency, ***Storm Water Management For Construction Activities***, EPA-832-R- 92-005, Washington, DC, September, 1992.

Washington State Department of Ecology, ***Stormwater Management Manual for the Puget Sound Basin***, Olympia, WA, February, 1992.

Sediment Trap

A sediment trap is formed by excavating a pond or by placing an earthen embankment across a low area or drainage swale. An outlet or spillway is constructed using large stones or aggregate to slow the release of runoff. The trap retains the runoff long enough to allow most of the silt to settle out.



Purpose

A sediment trap intercepts sediment-laden runoff from small disturbed areas and detains it long enough for the majority of the sediment to settle out.

Where Practice Applies

A sediment trap is installed:

- As close to the disturbed area or source of sediment as physically possible;
- Where the drainage area is less than 5 acres; and
- Where runoff from undisturbed areas can be excluded from the structure.

A sediment trap may be used in conjunction with other temporary measures, such as gravel construction entrances, vehicle wash areas, slope drains, diversion dikes and swales, or diversion channels.

Advantages

- Reduced sediment deposits downstream.
- Is inexpensive and simple to install.
- Can simplify the design process by trapping sediment at specific spots onsite.
- Disadvantages/Problems
- Effective only if properly maintained.
- Will not remove very fine silts and clays.
- Serves only limited areas.

Planning Considerations

Temporary sediment traps are usually installed in drainage ways with small watersheds. They may be used at a storm drain inlet or outlet.

Locate sediment trap as near the sediment source as topography allows.

Divert runoff from all undisturbed areas away from sediment trap.

Sediment traps should be installed before any land disturbance takes place in the drainage area.

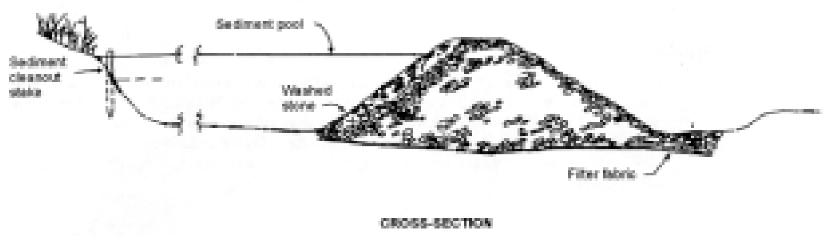
Design Recommendations

Drainage area - Not more than 5 acres.
Sediment storage - The sediment trap should have a minimum volume based on ½ inch of storage for each acre of drainage area. This volume equates to 1800 cubic feet of storage or 67 cubic yards for each acre of drainage area.
Trap efficiency - Length-to-width ratio should be 2:1 or greater; divert inflow to upper end of basin to avoid short-circuiting flow. Length is defined as the average distance from the inlet to the outlet of the trap.
Structure life - Limited to 2 years.
Embankment - The maximum height of the sediment trap embankment should be 5 feet when measured from the lowest point of natural ground on the downstream side of the embankment. The minimum top width of the embankment should be 5 feet. The side slopes of the embankment should be 2:1, horizontal to vertical, or flatter.
Excavations - When excavation is necessary to obtain the required storage, the side slopes should be no steeper than 2:1, horizontal to vertical, in the excavated portion of the basin.
Outlets - The outlet should be designed so that sediment does not leave the trap and erosion does not take place below the outlet. The outlets must empty onto undisturbed ground, into a water course, stabilized channel or a storm sewer system.
Capacity - 10-yr peak storm.
Stone - Hard, angular, well-graded mixture with “d50” of 9 inches minimum. Inside facing lined with a 1-foot thick layer of ½- to ¾-inch washed aggregate.
Side slopes - Spillway and excavated basin, 2:1 or flatter.
Protection from “piping” - Filter fabric or a cut-off trench is required between the stone spillway outlet section and the compacted embankment.
Spillway depth - 1.5 ft minimum below designed, settled top of embankment. Freeboard - 0.5 foot minimum.

Spillway width

Drainage Area (acres)	Minimum Bottom Width (feet)
1	4.0
2	6.0
3	8.0
4	10.0
5	12.0

Outlet apron - 5-ft long, minimum, on level grade with filter fabric foundation.



Construction Recommendations

Embankment

- Clear, grub, and strip all vegetation and root mat from area of embankment. Use stable mineral soil free of roots, rocks, debris, organic material, and other objectionable material.
- Place embankment fill in 9-inch lifts, maximum. The fill should be compacted by routing construction equipment so that the entire area of the fill is transversed by at least one wheel or tread track of the equipment. Construct side slopes 2:1 or flatter (3:1 recommended for backslope to improve stability of stone spillway).
- Overfill embankment to 6 inches above design elevation to allow for settlement.
- Outlet crest elevations should be at least one foot below the top of the embankment.

Outlet Section

- Excavate trapezoidal stone outlet section from compacted embankment. Allow for thickness of stone side slopes (21 inches minimum).
- Install filter fabric under riprap. Extend fabric up the sides to top of embankment.

A Place specified stone to lines and grades shown on plans, working the smaller stones into the voids to achieve a dense mass. Spillway crest must be level with minimum inside dimension specified in plan. Measure spillway depth from the highest stones in the spillway to the design elevation of dam. Minimum depth is 1.5 foot.

- Keep sides of the stone outlet section at least 21 inches thick through the level section and the downstream face of dam.
- Extend outlet apron below toe of dam on level grade until stable conditions are reached (5 feet minimum). Edges and end of the stone apron section must be flush with surrounding ground. No overfall should exist.
- Cover inside face of stone outlet section with a 1-foot thick layer of ½- to ¾-inch aggregate.

Vegetation

All embankments, earth spillways, and disturbed areas downstream from the structure should be vegetated within 3 days of completion of the construction of the structure. If the structure is not planned for more than one vegetative growing season, the structure may be vegetated using in **Temporary Seeding** recommendations. Basins that will be carried over the winter and into the next vegetative growing season should be vegetated using **Permanent Seeding** recommendations.

Common Trouble Points

Inadequate spillway size
Results in overtopping of dam, poor trap efficiency and possible failure of the structure. Modification of the plan may be required.

Omission of or improper installation of filter fabric
Results in washout under sides or bottom of the stone outlet section (piping).

Low point in embankment caused by inadequate compaction and settling
Results in overtopping and possible failure.

Stone outlet apron does not extend to stable grade
Results in erosion below the dam.

Stone size too small or backslope too steep
Results in stone displacement.

Inadequate vegetative protection
Results in erosion of embankment.

Inadequate storage capacity
Sediment not removed from basin frequently enough.

Contact slope between stone spillway and earth embankment too steep
Piping failure is likely.

Maintenance

The effective life of a sediment trap depends upon adequate maintenance. The trap should be readily accessible for periodic maintenance and sediment removal.

Set a stake at one-half the design depth. This will be the "cleanout level." Remove sediment when it has accumulated to one-half the design depth.

Inspect sediment traps after each significant rainfall event. Repair any erosion and piping holes immediately.

Clean or replace spillway gravel facing if clogged.

Promptly replace any displaced riprap, being careful that no stones in the spillway are above design grade.

Inspect vegetation; reseed and remulch if necessary.

Check spillway depth periodically to ensure minimum of 1.5 ft depth from lowest point of the settled embankment to highest point of spillway crest. Fill any low areas of the embankment to maintain design elevation.

After all sediment-producing areas have been stabilized, inspected, and approved, remove the structure and all unstable sediment. Smooth site to blend with adjoining areas and stabilize in accordance with vegetation plan.

References

Minnick, E. L., and H. T. Marshall, ***Stormwater Management and Erosion Control for Urban and Developing Areas in New Hampshire***, Rockingham County Conservation District, August 1992.

North Carolina Department of Environment, Health, and Natural Resources, ***Erosion and Sediment Control Field Manual***, Raleigh, NC, February 1991.

U.S. Environmental Protection Agency, ***Storm Water Management For Construction Activities***, EPA-832-R- 92-005, Washington, DC, September, 1992.

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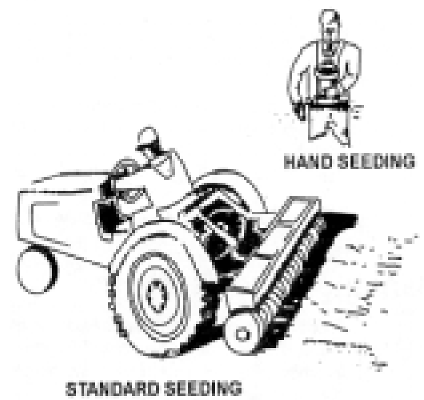
Seeding, Permanent

The establishment of perennial vegetative cover on disturbed areas.



Purpose

Permanent seeding of grass and planting trees and shrubs provides stabilization to the soil by holding soil particles in place.

Vegetation reduces sediments and runoff to downstream areas by slowing the velocity of runoff and permitting greater infiltration of the runoff.

Vegetation also filters sediments, helps the soil absorb water, improves wildlife habitats, and enhances the aesthetics of a site.

Where Practice Applies

- Permanent seeding and planting is appropriate for any graded or cleared area where long-lived plant cover is needed to stabilize the soil.
- Areas which will not be brought to final grade for a year or more.
- Some areas where permanent seeding is especially important are filter strips, buffer areas, vegetated swales, steep slopes, and stream banks.
- This practice is effective on areas where soils are unstable because of their texture or structure, high water table, winds, or steep slope.

Advantages

Advantages of seeding over other means of establishing plants include the small initial establishment cost, the wide variety of grasses and legumes available, low labor requirement, and ease of establishment in difficult areas.

Seeding is usually the most economical way to stabilize large areas.

Well established grass and ground covers can give an aesthetically pleasing, finished look to a development.

Once established, the vegetation will serve to prevent erosion and retard the velocity of runoff.

Disadvantages/Problems

Disadvantages which must be dealt with are the potential for erosion during the establishment stage, a need to reseed areas that fail to establish, limited periods during the year suitable for seeding, and a need for water and appropriate climatic conditions during germination. Vegetation and mulch cannot prevent soil slippage and erosion if soil is not inherently stable.

Coarse, high grasses that are not mowed can create a fire hazard in some locales. Very short mowed grass, however, provides less stability and sediment filtering capacity.

Grass planted to the edge of a watercourse may encourage fertilizing and mowing near the water's edge and increase nutrient and pesticide contamination.

Depends initially on climate and weather for success.

May require regular irrigation to establish and maintain.

Planning considerations

Selection of the right plant materials for the site, good seedbed preparation, timing, and conscientious maintenance are important. Whenever possible, native species of plants should be used for landscaping. These plants are already adapted to the locale and survivability should be higher than with "introduced" species.

Native species are also less likely to require irrigation, which can be a large maintenance burden and is neither cost-effective nor ecologically sound.

If non-native plant species are used, they should be tolerant of a large range of growing conditions, as low-maintenance as possible, and not invasive.

Consider the microclimate within the development area. Low areas may be frost pockets and require hardier vegetation since cold air tends to sink and flow towards low spots. South-facing slopes may be more difficult to re-vegetate because they tend to be sunnier and drier.

Divert as much surface water as possible from the area to be planted.

Remove seepage water that would continue to have adverse effects on soil stability or the protecting vegetation. Subsurface drainage or other engineering practices may be needed. In this situation, a permit may be needed from the local Conservation Commission: check ahead of time to avoid construction delays.

Provide protection from equipment, trampling and other destructive agents.

Vegetation cannot be expected to supply an erosion control cover and prevent slippage on a soil that is not stable due to its texture, structure, water movement, or excessive slope.

Seeding Grasses and Legumes

Install needed surface runoff control measures such as gradient terraces, berms, dikes, level spreaders, waterways, and sediment basins prior to seeding or planting.

Seedbed Preparation

If infertile or coarse-textured subsoil will be exposed during land shaping, it is best to stockpile topsoil and respread it over the finished slope at a minimum 2- to 6-inch depth and roll it to provide a firm seedbed. If construction fill operations have left soil exposed with a loose, rough, or irregular surface, smooth with blade and roll.

Loosen the soil to a depth of 3-5 inches with suitable agricultural or construction equipment.

Areas not to receive top soil shall be treated to firm the seedbed after incorporation of the lime and fertilizer so that it is depressed no more than ½ - 1 inch when stepped on with a shoe. Areas to receive topsoil shall not be firmed until after topsoiling and lime and fertilizer is applied and incorporated, at which time it shall be treated to firm the seedbed as described above. This can be done by rolling or cultipacking.

Cool Season Grasses

Cool Season Grasses grow rapidly in the cool weather of spring and fall, and set seed in June and July. Cool season grasses become dormant when summer temperatures persist above 85 degrees and moisture is scarce.

Lime and Fertilizer

Apply lime and fertilizer according to soil test and current Extension Service recommendations. In absence of a soil test, apply lime (a pH of 5.5 - 6.0 is desired) at a rate of 2.5 tons per acre and 10-20-20 analysis fertilizer at a rate of 500 pounds per acre (40 % of N to be in an organic or slow release form). Incorporate lime and fertilizer into the top 2-3 inches of soil.

Seeding Dates

Seeding operations should be performed within one of the following periods:

- April 1 - May 31,
- August 1 - September 10,
- November 1 - December 15 as a dormant seeding (seeding rates shall be increased by 50% for dormant seedings).

Seeding Methods

Seeding should be performed by one of the following methods. Seed should be planted to a depth of ¼ to ½ inches.

- Drill seedings,
- Broadcast and rolled, cultipacked or tracked with a small track piece of construction equipment,
- Hydroseeding, with subsequent tracking.

Mulch

Mulch the seedings with straw applied at the rate of ½ tons per acre. Anchor the mulch with erosion control netting or fabric on sloping areas.

Warm Season Grasses

Warm Season Grasses begin growth slowly in the spring, grow rapidly in the hot summer months and set seed in the fall. Many warm season grasses are sensitive to frost in the fall, and the top growth may die back. Growth begins from the plant base the following spring.

Lime and Fertilizer

Lime to attain a pH of at least 5.5. Apply a 0-10-10 analysis fertilizer at the rate of 600 lbs./acre.
Incorporate both into the top 2-3 inches of soil. (30 lbs. of slow release nitrogen should be applied after emergence of grass in the late spring.)

Seeding Dates

Seeding operations should be performed as an early spring seeding (April 1-May 15) with the use of cold treated seed. A late fall early winter dormant seeding (November 1 - December 15) can also be made, however the seeding rate will need to be increased by 50%.

Seeding Methods

Seeding should be performed by one of the following methods:

- Drill seedings (de-awned or de-bearded seed should be used unless the drill is equipped with special features to accept awned seed).
- Broadcast seeding with subsequent rolling, cultipacking or tracking the seeding with small track construction equipment. Tracking should be oriented up and down the slope.
- Hydroseeding with subsequent tracking. If wood fiber mulch is used, it should be applied as a separate operation after seeding and tracking to assure good seed to soil contact.

Mulch

Mulch the seedings with straw applied at the rate of ½ tons per acre. Anchor the mulch with erosion control netting or fabric on sloping areas.

Seed Mixtures for Permanent Cover

Recommended mixtures for permanent seeding are provided on the following pages. Select plant species which are suited to the site conditions and planned use. Soil moisture conditions, often the major limiting site factor, are usually classified as follows:

Dry - Sands and gravels to sandy loams. No effective moisture supply from seepage or a high water table.

Moist - Well drained to moderately well drained sandy loams, loams, and finer; or coarser textured material with moderate influence on root zone from seepage or a high water table.

Wet - All textures with a water table at or very near the soil surface, or with enduring seepage.

When other factors strongly influence site conditions, the plants selected must also be tolerant of these conditions.

Permanent Seeding Mixtures

Mix	Site	Seed Mixture	Seed, Pounds per: Acre	1,000 sf	Remarks
1	Dry	Little Bluestem			* Use Warm Season planting procedure.
		or Broomsedge	10	0.25	* Roadsides
		Tumble Lovegrass*	1	0.10	* Sand and Gravel Stabilization
		Switchgrass	10	0.25	* Clover requires inoculation with nitrogen-fixing bacteria
		Bush Clover*	2	0.10	
		Red Top	1	0.10	* Rates for this mix are for PLS.
2	Dry	Deertongue	15	0.35	* Use Warm Season planting procedures.
		Broomsedge	10	0.25	* Acid sites/Mine spoil
		Bush Clover*	2	0.10	* Clover requires inoculation with nitrogen-fixing bacteria.
		Red Top	1	0.10	*Rates for this mix are for PLS.
3	Dry	Big Bluestem	10	0.25	* Use Warm Season planting procedures.
		Indian Grass	10	0.25	* Eastern Prairie appearance
		Switchgrass	10	0.25	* Sand and Gravel pits.
		Little Bluestem	10	0.25	* Golf Course Wild Areas
		Red Top or	1	0.10	* Sanitary Landfill Cover seeding
		Perennial Ryegrass	10	0.25	* Wildlife Areas *OK to substitute Poverty Dropseed in place of Red Top/Ryegrass. *Rates for this mix are for PLS.
4	Dry	Flat Pea	25	0.60	* Use Cool Season planting procedures
		Red Top or	2	0.10	* Utility Rights-of-Ways (tends to suppress woody growth)
		Perennial Ryegrass	15	0.35	
5	Dry	Little Bluestem	5	0.10	* Use Warm Season planting procedures.
		Switchgrass	10	0.25	* Coastal sites
		Beach Pea*	20	0.45	* Rates for Bluestein and Switchgrass are for PLS.
		Perennial Ryegrass	10	0.25	
6	Dry - Moist	Red Fescue	10	0.25	* Use Cool Season planting procedure.
		Canada Bluegrass	10	0.25	* Provides quick cover but is non-aggressive; will tend to allow indigenous plant colonization.
		Perennial Ryegrass	10	0.25	
		Red Top	1	0.10	* General erosion control on variety of sites, including forest roads, skid trails and landings.
7	Moist-Wet	Switchgrass	10	0.25	* Use Warm Season planting procedure.
		Virginia Wild Rye	5	0.10	* Coastal plain/flood plain
		Big Bluestem	15	0.35	* Rates for Bluestem and Switchgrass are for PLS.
		Red Top	1	0.10	

Permanent Seeding Mixtures

Mix	Site	Seed Mixture	Seed, Pounds per: Acre	Seed, Pounds per: 1,000 sf	Remarks
8	Moist	Creeping Bentgrass	5	0.10	* Use Cool Season planting procedures.
	Wet	Fringed Bromegrass	5	0.10	* Pond Banks
		Fowl Meadowgrass	5	0.10	* Waterways/ditch banks
		Bluejoint Reedgrass or Rice Cutgrass	2	0.10	
		Perennial Ryegrass	10	0.25	
9	Moist	Red Fescue	5	0.10	*Salt Tolerant
	Wet	Creeping Bentgrass	2	0.10	* Fescue and Bentgrass provide low growing appearance, while Switchgrass provides tall cover for wildlife.
		Switchgrass	8	0.20	
		Perennial Ryegrass	10	0.25	
10	Moist	Red Fescue	5	0.10	* Use Cool Season planting procedure.
	Wet	Creeping Bentgrass	5	0.10	* Trefoil requires inoculation with nitrogen fixing bacteria.
		Virginia Wild Rye	8	0.20	
		Wood Reed Grass*	1	0.10	* Suitable for forest access roads, skid trails and other partial shade situations.
		Showy Tick Trefoil*	1	0.10	
11	Moist	Creeping Bentgrass	5	0.10	* Use Cool Season planting procedure.
	Wet	Bluejoint Reed Grass	1	0.10	* Suitable for waterways, pond or ditch banks.
		Virginia Wild Rye	3	0.10	* Trefoil requires inoculation with nitrogen fixing bacteria.
		Fowl Meadow Grass	10	0.25	
		Showy Tick Trefoil*	1	0.10	
		Red Top	1	0.10	
12	Wet	Blue Joint Reed Grass	1	0.10	* Use Cool Season planting procedure.
		Canada Manna Grass	1	0.10	* OK to seed in saturated soil conditions, but not in standing water.
		Rice Cut Grass	1	0.10	
		Creeping Bent Grass	5	0.10	* Suitable as stabilization seeding for created wetland.
		Fowl Meadow Grass	5	0.10	* All species in this mix are native to Massachusetts.
13	Dry - Moist	American Beachgrass	18” centers	18’ centers	*Vegetative planting with dormant culms, 3-5 culms per planting
14	Inter- Tidal	Smooth Cordgrass Saltmeadow Cordgrass	12-18” centers	12-18” centers	* Vegetative planting with transplants.

Notes:
* Species such as Tumble Lovegrass, Fringed Bromegrass, Wood Reedgrass, Bush Clover and Beach Pea, while known to be commercially available from specific seed suppliers, may not always be available from your particular seed suppliers. The local Natural Resources Conservation Service office may be able to help with a source of supply. In the event a particular species listed in a mix can not be obtained, however, it may be possible to substitute another species.

Seed mixtures by courtesy of Natural Resources Conservation Service, Amherst, MA.

(PLS) Pure Live Seed

Warm Season grass seed is sold and planted on the basis of pure live seed. An adjustment is made to the bulk rate of the seed to compensate for inert material and non-viable seed. Percent of pure live seed is calculated by multiplying the percent purity by the percent germination; **(% purity) x (% germination) = percent PLS.**

For example, if the seeding rate calls for 10 lbs./acre PLS and the seed lot has a purity of 70% and germination of 75%, the PLS factor is:

(.70 x .75) =.53

10 lbs. divided by .53 = approx. 19 lbs.

Therefore, 19 lbs of seed from the particular lot will need to be applied to obtain 10 lbs. of pure live seed.

Special Note

Tall Fescue, Reed Canary Grass, Crownvetch and Birdsfoot Trefoil are no longer recommended for general erosion control use in Massachusetts due to the invasive characteristics of each. If these species are used, it is recommended that the ecosystem of the site be analyzed for the effects species invasiveness may impose. The mixes listed in the above mixtures include either species native to Massachusetts or non-native species that are not perceived to be invasive, as per the Massachusetts Native Plant Advisory Committee.

Wetlands Seed Mixtures

For newly created wetlands, a wetlands specialist should design plantings to provide the best chance of success. Do not use introduced, invasive plants like reed canarygrass (Phalaris arundinacea) or purple loosestrife (Lythrum salicaria). Using plants such as these will cause many more problems than they will solve.

The following grasses all thrive in wetland situations:

- Fresh Water Cordgrass (*Spartina pectinata*)
- Marsh/Creeping Bentgrass (*Agrostis stolonifera, var. Palustric*)
- Broomsedge (*Andropogon virginicus*)
- Fringed Bromegrass (*Bromus ciliatus*)
- Blue Joint Reed Grass (*Calamagrostis cavedensis*)
- Fowl Meadow Grass (*Glyceria striata*)
- Riverbank Wild Rye (*Elymus riparius*)
- Rice Cutgrass (*Leersia oryzoides*)
- Stout Wood Reed (*Cinna arundinacea*)
- Canada Manna Grass (*Glyceria canadensis*)

A sample wetlands seed mix developed by The New England Environmental Wetland Plant Nursery is shown on the following page.

Wetland Seed Mixture

The New England Environmental Wetland Plant Nursery has developed a seed mixture which is specifically designed to be used in wetland replication projects and stormwater detention basins. It is composed of seeds from a variety of indigenous wetland species. Establishing a native wetland plant understory in these areas provides quick erosion control, wildlife food and cover, and helps to reduce the establishment of undesirable invasive species such as Phragmites and purple loosestrife (Lythrum salicaria). The species have been selected to represent varying degrees of drought tolerance, and will establish themselves based upon microtopography and the resulting variation in soil moisture.

Common Name (*Scientific Name*)	**% in Mix**	**Comments**
Lurid Sedge (*Carex lurida*)	30	A low ground cover that tolerates mesic sites in addition to saturated areas; prolific seeder in second growing season.
Fowl Meadow Grass (*Glyceria Canadensis*)	25	Prolific seed producer that is a valuable wildlife food source.
Fringed Sedge (*Carex crinita*)	10	A medium to large sedge that tolerates saturated areas; good seed producer.
Joe-Pye Weed (*Eupatoriadelphus maculatus*)	10	Flowering plant that is valuable for wildlife cover. Grows to 4 feet.
Brook Sedge (*Carex spp., Ovales group*)	10	Tolerates a wide range of hydrologic conditions.
Woolgrass (*Scirpus cyperinus*)	5	Tolerates fluctuating hydrology.
Boneset (*Eupatorium perfoliatum*)	5	Flowering Plant that is valuable for wildlife cover. Grows to 3 feet.
Tussock Sedge (*Carex stricta*)	<5	Grows in elevated hummocks on wet sites, may grow rhizomonously on drier sites.
Blue Vervain (*Verbena hastata*)	<5	A native plant that bears attractive, blue flowers.

The recommended application rate is one pound per 5,000 square feet when used as an understory cover. This rate should be increased to one pound per 2,500 square feet for detention basins and other sites which require a very dense cover. For best results, a late fall application is recommended. This mix is not recommended for standing water.

Maintenance

Inspect seeded areas for failure and make necessary repairs and reseed immediately. Conduct or follow-up survey after one year and replace failed plants where necessary.

If vegetative cover is inadequate to prevent rill erosion, overseed and fertilize in accordance with soil test results.

If a stand has less than 40% cover, reevaluate choice of plant materials and quantities of lime and fertilizer. Re-establish the stand following seedbed preparation and seeding recommendations, omitting lime and fertilizer in the absence of soil test results. If the season prevents resowing, mulch or jute netting is an effective temporary cover.

Seeded areas should be fertilized during the second growing season. Lime and fertilize thereafter at periodic intervals, as needed.

References

North Carolina Department of Environment, Health, and Natural Resources, ***Erosion and Sediment Control Field Manual***, Raleigh, NC, February 1991.

Personal communication, Richard J. DeVergilio, USDA, Natural Resources Conservation Service, Amherst, MA.

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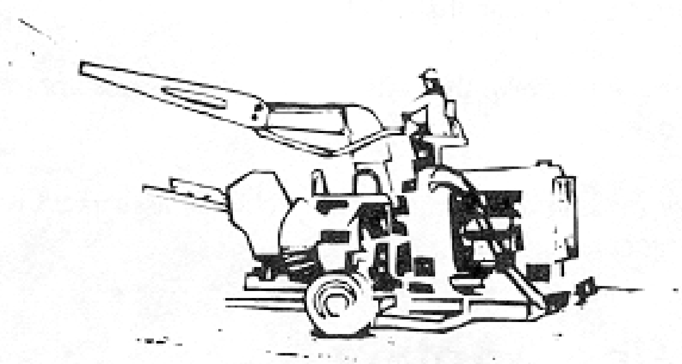
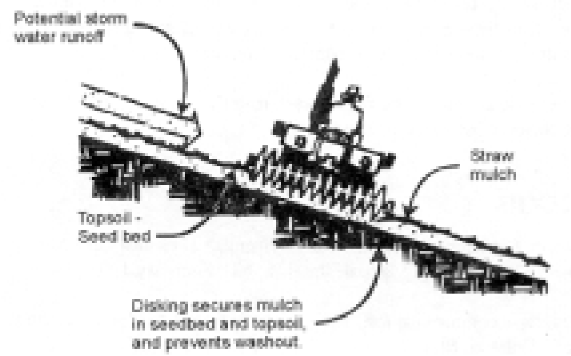


HYDRO-SEEDING

Seeding, Temporary

Planting rapid-growing annual grasses, small grains, or legumes to provide initial, temporary cover for erosion control on disturbed areas.

Purpose



To temporarily stabilize areas that will not be brought to final grade for a period of more than 30 working days.
To stabilize disturbed areas before final grading or in a season not suitable for permanent seeding.
Temporary seeding controls runoff and erosion until permanent vegetation or other erosion control measures can be established.
Root systems hold down the soils so that they are less apt to be carried offsite by storm water runoff or wind.
Temporary seeding also reduces the problems associated with mud and dust from bare soil surfaces during construction.

Where Practice Applies

On any cleared, unvegetated, or sparsely vegetated soil surface where vegetative cover is needed for less than one year. Applications of this practice include diversions, dams, temporary sediment basins, temporary road banks, and topsoil stockpiles.

Where permanent structures are to be installed or extensive re-grading of the area will occur prior to the establishment of permanent vegetation.

Areas which will not be subjected to heavy wear by construction traffic.

Areas sloping up to 10% for 100 feet or less, where temporary seeding is the only practice used.

Advantages

This is a relatively inexpensive form of erosion control but should only be used on sites awaiting permanent planting or grading. Those sites should have permanent measures used.

Vegetation will not only prevent erosion from occurring, but will also trap sediment in runoff from other parts of the site.

Temporary seeding offers fairly rapid protection to exposed areas.

Disadvantages/Problems

Temporary seeding is only viable when there is a sufficient window in time for plants to grow and establish cover. It depends heavily on the season and rainfall rate for success.

If sown on subsoil, growth will be poor unless heavily fertilized and limed. Because overfertilization can cause pollution of stormwater runoff, other practices such as mulching alone may be more appropriate. The potential for over-fertilization is an even worse problem in or near aquatic systems.

Once seeded, areas should not be travelled over.

Irrigation may be needed for successful growth. Regular irrigation is not encouraged because of the expense and the potential for erosion in areas that are not regularly inspected.

Planning Considerations

Temporary seedings provide protective cover for less than one year. Areas must be reseeded annual or planted with perennial vegetation.

Temporary seeding is used to protect earthen sediment control practices and to stabilize denuded areas that will not be brought into final grade for several weeks or months. Temporary seeding can provide a nurse crop for permanent vegetation, provide residue for soil protection and seedbed preparation, and help prevent dust production during construction.

Use low-maintenance native species wherever possible.

Planting should be timed to minimize the need for irrigation.

Sheet erosion, caused by the impact of rain on bare soil, is the source of most fine particles in sediment. To reduce this sediment load in runoff, the soil surface itself should be protected. The most efficient and economical means of controlling sheet and rill erosion is to establish vegetative cover. Annual plants which sprout rapidly and survive for only one growing season are suitable for establishing temporary vegetative cover. Temporary seeding is effective when combined with construction phasing so bare areas of the site are minimized at all times.

Temporary seeding may prevent costly maintenance operations on other erosion control systems. For example, sediment basin clean-outs will be reduced if the drainage area of the basin is seeded where grading and construction are not taking place. Perimeter dikes will be more effective if not choked with sediment.

Proper seedbed preparation and the use of quality seed are important in this practice just as in permanent seeding. Failure to carefully follow sound agronomic recommendations will often result in an inadequate stand of vegetation that provides little or no erosion control.

Soil that has been compacted by heavy traffic or machinery may need to be loosened. Successful growth usually requires that the soil be tilled before the seed is applied. Topsoiling is not necessary for temporary seeding; however, it may improve the chances of establishing temporary vegetation in an area.

Planting Procedures

Time of Planting

Planting should preferably be done between April 1 and June 30, and September 1 through September 30. If planting is done in the months of July and August, irrigation may be required. If planting is done between October 1 and March 31, mulching should be applied immediately after planting. If seeding is done during the summer months, irrigation of some sort will probably be necessary.

Site Preparation

Before seeding, install needed surface runoff control measures such as gradient terraces, interceptor dike/swales, level spreaders, and sediment basins.

Seedbed Preparation

The seedbed should be firm with a fairly fine surface.

Perform all cultural operations across or at right angles to the slope. See **Topsoiling** and **Surface Roughening** for more information on seedbed preparation. A minimum of 2 to 4 inches of tilled topsoil is required.

Liming and Fertilization

Apply uniformly 2 tons of ground limestone per acre (100 lbs. per 1,000 Sq. Ft.) or according to soil test.

Apply uniformly 10-10-10 analysis fertilizer at the rate of 400 lbs. per acre (14 lbs. per 1,000 Sq. Ft.) or as indicated by soil test. Forty percent of the nitrogen should be in organic form.

Work in lime and fertilizer to a depth of 4 inches using any suitable equipment.

Seedings for Temporary Cover

Species	**Seeding Rates lbs/sq.ft.** 1,000 Sq.Ft.	Acre	**Recommended Seeding Dates**
Annual Ryegrass	1	40	April 1 to June 1 Aug. 15 to Sept. 15
Foxtail Millet	0.7	30	May 1 to June 30
Oats	2	80	April 1 to July 1 August 15 to Sept. 15
Winter Rye	3	120	Aug. 15 to Oct. 15

“Hydro-seeding” applications with appropriate seed-mulch-fertilizer mixtures may also be used.

Seeding

Select adapted species from the accompanying table.
Apply seed uniformly according to the rate indicated in the table by broadcasting, drilling or hydraulic application.
Cover seeds with suitable equipment as follows:

Rye grass	¼ inch
Millet	½ to ¾ inch
Oats	1 to 1-1/2 inches
Winter rye	1 to 1-1/2 inches.

Mulch

Use an effective mulch, such as clean grain straw; tacked and/or tied down with netting to protect seedbed and encourage plant growth.

Common Trouble Points

Lime and fertilizer not incorporated to at least 4 inches
May be lost to runoff or remain concentrated near the surface where they may inhibit germination.

Mulch rate inadequate or straw mulch not tacked down
Results in poor germination or failure, and erosion damage. Repair damaged areas, reseed and mulch.

Annual ryegrass used for temporary seeding
Ryegrass reseeds itself and makes it difficult to establish a good cover of permanent vegetation.

Seed not broadcast evenly or rate too low
Results in patchy growth and erosion.

Maintenance

Inspect within 6 weeks of planting to see if stands are adequate. Check for damage after heavy rains. Stands should be uniform and dense. Fertilize, reseed, and mulch damaged and sparse areas immediately. Tack or tie down mulch as necessary.

Seeds should be supplied with adequate moisture. Furnish water as needed, especially in abnormally hot or dry weather or on adverse sites. Water application rates should be controlled to prevent runoff.

References

Massachusetts Department of Environmental Protection, Office of Watershed Management, Nonpoint Source Program, Massachusetts ***Nonpoint Source Management Manual,*** Boston, Massachusetts, June, 1993.

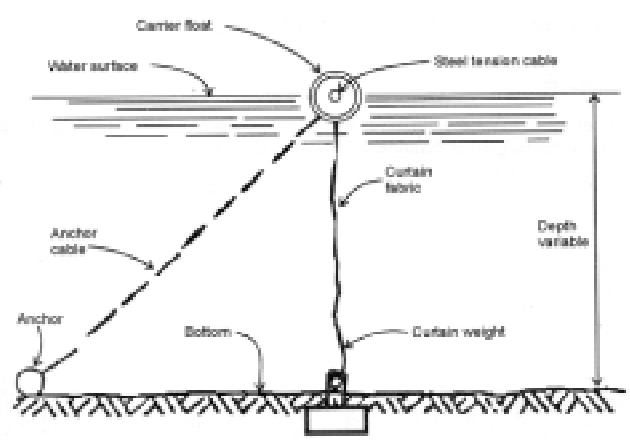
North Carolina Department of Environment, Health, and Natural Resources, ***Erosion and Sediment Control Field Manual***, Raleigh, NC, February 1991.

U.S. Environmental Protection Agency, ***Storm Water Management For Construction Activities***, EPA-832-R- 92-005, Washington, DC, September, 1992.

Washington State Department of Ecology, ***Stormwater Management Manual for the Puget Sound Basin***, Olympia, WA, February, 1992.

Silt Curtain

A temporary sediment barrier installed parallel to the bank of a stream or lake. Used to contain the sediment produced by construction operations on the bank of a stream or lake and allow for its removal.



Where Practice Applies

The silt curtain is used along the banks of streams or lakes where sediment could pollute or degrade the stream or lake.

Planning Considerations

A silt curtain is useful where construction is on the bank of a stream or lake and coarse sediment is a major concern. A silt curtain will not keep the water from being muddy during construction operations, but it will contain the coarse sediment to the construction area. The curtain should obstruct the flow as little as possible to reduce the chance of failure.

Installation Recommendations

The silt curtain should be a filter fabric recommended by the manufacturer for use as a silt curtain. Both ends of the silt curtain should be tied into the bank. The silt curtain should be placed as close as possible to the bank, allowing room for construction operations inside the protected area. In a flowing stream, remove trapped sediment before removing the silt curtain.

The curtain should be anchored to the bottom so sediment cannot go beneath the curtain. It should extend above normal water level. It can be supported by either stakes or floats of adequate strength.

Maintenance

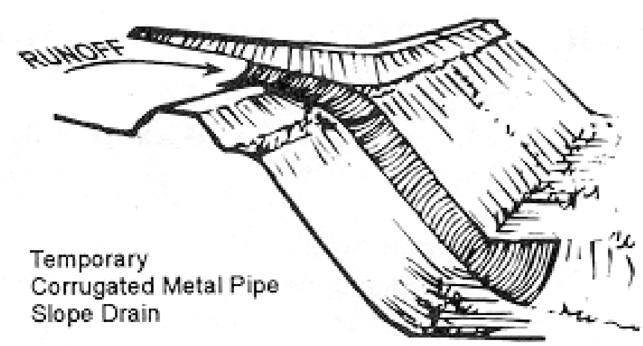
Accumulated sediment must be removed periodically. The curtain must be inspected often and after each storm. Any damage must be immediately repaired.

References

Connecticut Council on Soil and Water Conservation, ***Connecticut Guidelines for Soil Erosion and Sediment Control***, Hartford, CT, January, 1985.

Slope Drain, Temporary

A pipe extending from the top to the bottom of a cut or fill slope and discharging into a stabilized water course or a sediment trapping device or onto a stabilization area. Used to carry concentrated runoff down steep slopes without causing gullies, channel erosion, or saturation of slide-prone soils until permanent water disposal measures can be installed.



Where Practice Applies

This practice applies to construction areas where storm water runoff above a cut or fill will cause erosion if allowed to flow over the slope.

Advantages

Slope drains provide a potentially effective method of conveying water safely down steep slopes.

Disadvantages/Problems

Care must be taken to correctly site drains and not underdesign them. Also, when clearing takes place prior to installing these drains, care must be taken to revegetate the entire easement area, otherwise erosion tends to occur beneath the pipeline, resulting in gully formation.

Planning Considerations

Temporary slope drains are generally used in conjunction with diversions to convey runoff down a slope until permanent water disposal measures can be installed.

There is often a significant lag between the time a cut or fill slope is completed and the time a permanent drainage system can be installed. During this period, the slope is particularly vulnerable to erosion. This situation also occurs on slope construction which is temporarily delayed before final grade is reached.

When used in conjunction with diversion dikes, temporary slope drains can be used to convey stormwater from the entire drainage area above a slope to the base of the slope without erosion.

Slope drains must extend downslope to stable outlets, or special outlet protection must be provided.

It is very important that these temporary structures be sized, installed, and maintained properly since their failure will often result in severe gully erosion. The entrance section must be securely entrenched, all connections must be watertight, and the conduit must be staked securely.

Temporary slope drains should be replaced with more permanent structures as soon as construction activities permit.

Design Recommendations

Capacity

Sufficient to handle a 10-year peak flow. Permanent pipe slope drains should be sized for the 25-year peak flow.

Drainage Area

The maximum drainage area recommended per pipe is ten acres. For larger areas, a rock-lined channel or more than one pipe should be installed.

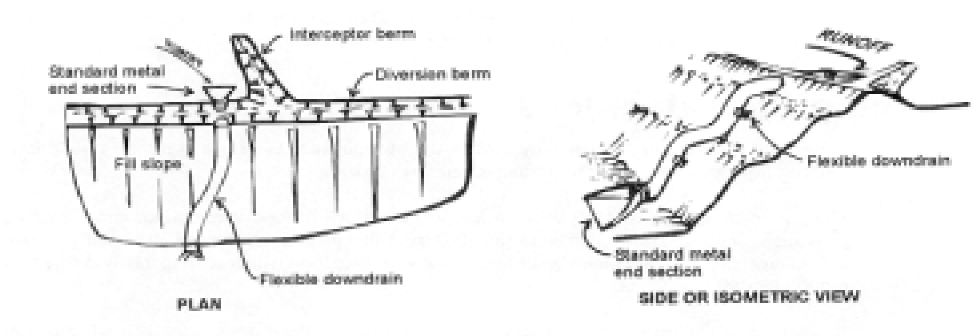
Material

Strong, flexible pipe such as heavy duty, non-perforated, corrugated plastic.

Pipe size

Based on drainage area:

Maximum Drainage Area Per Pipe (Acres)	Minimum Pipe Diameter (Inches)
0.5	12
0.75	15
1.0	18
>1.0	Individually designed



Entrance

The entrance should consist of a standard flared-end section with a minimum 6-inch metal toe plate to prevent runoff from undercutting the pipe inlet. The slope of the entrance should be at least 3 percent.

Connection to diversion ridge at top of slope: compacted fill over pipe with minimum dimensions 1.5-foot depth, 4-foot top width, and 0.5 foot higher than diversion ridge.

The soil around and under the pipe and entrance section should be thoroughly compacted to prevent undercutting.

The flared inlet section shall be securely connected to the slope drain and have watertight connecting bands.

Slope drain sections shall be securely fastened together and have gasketed watertight fittings, and be securely anchored into the soil.

Interceptor dikes

Interceptor dikes should be used as needed to direct runoff into a slope drain. The height of the dike should be at least 1 foot higher at all points than the top of the inlet pipe.

Outlet

The area below the outlet must be stabilized with a riprap apron.

If the pipe slope drain is conveying sediment-laden water, direct all flows into the sediment trapping facility.

Common Trouble Points

Washout along the pipe due to seepage and piping
inadequate compaction, insufficient fill, or installation too close to edge of slope.

Overtopping of diversion caused by undersized or blocked pipe
Drainage area may be too large.
Overtopping of diversion caused by improper grade of channel and ridge Maintain positive grade.
Overtopping due to poor entrance conditions and trash build up at pipe inlet Deepen and widen channel at pipe entrance; inspect and clear inlet frequently.
Erosion at outlet
Pipe not extended to stable grade or outlet stabilization structure needed.
Displacement or separation of pipe
Tie pipe down and secure joints.
CAUTION!!
Do not divert more water to the slope drain than it was designed to carry.

Maintenance

Failure of a temporary slope drain can cause severe erosion damage. This practice requires intensive maintenance. Inspect slope drains and supporting diversions once a week and after every rainfall event.

Check inlet for sediment or trash accumulation. Clear inlet and restore proper entrance condition. The inlet should be free of undercutting, and no water should be going around the point of entry. If there are problems, the headwall should be reinforced with compacted earth or sand bags.

Check fill over pipe for settlement, cracking, or piping holes. Repair immediately.

Check for seepage holes at point where pipe emerges from dike. Repair immediately.

Check conduit for evidence of leaks or inadequate lateral support. Repair immediately.

Check outlet for erosion or sedimentation. Clean, repair, or extend as needed.

When slopes have been stabilized, inspected, and approved, remove temporary diversions and slope drains and stabilize all disturbed areas.

References

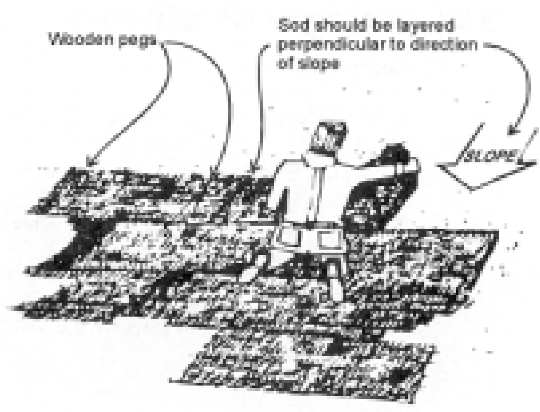
Massachusetts Department of Environmental Protection, Office of Watershed Management, Nonpoint Source Program, ***Massachusetts Nonpoint Source Management Manual,*** Boston, Massachusetts, June, 1993.

North Carolina Department of Environment, Health, and Natural Resources, ***Erosion and Sediment Control Field Manual***, Raleigh, NC, February 1991.

Washington State Department of Ecology, ***Stormwater Management Manual for the Puget Sound Basin***, Olympia, WA, February, 1992.

Sodding

Stabilizing fine-graded disturbed areas by establishing permanent grass stands with sod. To provide immediate erosion protection or to stabilize drainageways where concentrated overland flow will occur.



Where Practice Applies

- Disturbed areas which require immediate vegetative cover.
- Waterways carrying intermittent flow: where immediate stabilization or aesthetics are factors; where velocities will not exceed that specified for a grass lining; and other locations which are particularly suited to stabilization with sod.
- Disturbed areas requiring immediate and permanent vegetative cover.

Locations best suited to stabilization with sod are:

- Areas around drop inlets, when the drainage area has been stabilized.
- Steep critical areas.
- If mowing is required, do not use grass sod on slopes steeper than 3:1. (Use minimum maintenance ground covers.)

Advantages

- Sod gives an immediate vegetative cover, which is both effective in checking erosion and is aesthetically pleasing.
- Provides more stabilizing protection than initial seeding through dense cover formed by sod.
- Produces lower weed growth than seeded vegetation.
- Can be used for site activities within a shorter time than can seeded vegetation.
- Can be placed at any time of the year as long as moisture conditions in the soil are favorable and the ground is not frozen.

Disadvantages/Problems

- Sod is expensive.
- Sod is heavy and handling costs are high.
- Good quality sod, free from weed species, may be difficult to obtain.
- If laid in an unfavorable season, midsummer irrigation may be required.
- Grass species in the sod may not be suitable for site conditions.
- If not anchored or drained properly, sod will "roll up" in grassed waterways.

Planning Considerations

Sod requires careful handling and is sensitive to transport and storage conditions. Soil preparation, installation, and proper maintenance are as important with sod as with seed.

Choosing the appropriate type of sod for site conditions and intended use is of the utmost importance.

Installation

Sod should be free of weeds and be of uniform thickness (approximately 1 inch) and should have a dense root mat for mechanical strength. Sodding is a very expensive method of establishing a grass-type cover but it has the benefit of giving "instant" protection for critical areas. This value may be well worth the higher expense.

Site Preparation

Rake or harrow to achieve a smooth, final grade. Roll or cultipack to create a smooth, firm surface on which to lay the sod. Do not install on compacted clay or pesticide-treated soil. Apply topsoil if needed.

Lime and Fertilizer

Lime according to soil test to pH 6.5, or in the absence of a soil test, apply lime at the rate of 2 to 3 tons of ground limestone per acre (10-15 lbs. per 100 sq. feet).

Fertilize according to soil test or at the rate of 500-1,000 lbs. per acre (1 ¼ to 2 ½ pounds per 100 sq. feet) of 10-5-5 or similar fertilizer. Fertilizer with 40% or more of the nitrogen in organic form is preferred.

Work the lime and fertilizer into the soil 1 or 2 inches deep, and smooth.

Sod

Select high-quality, healthy, vigorous certified-class sod which is at least one year old but not older than three years. It should be a variety that is well-adapted to the region and expected level of maintenance. Common sod types include: Kentucky bluegrass blends, Kentucky bluegrass/Fine fescue mixes and Tall fescue/Kentucky bluegrass mixture.

Sod should be machine cut to a uniform thickness of ¾ inch, plus or minus ¼ inch, at the time of cutting. Measurement of thickness should exclude top growth or thatch.

Standard size sections of sod should be strong enough to support their own weight and retain their size and shape when suspended vertically with a firm grasp of the upper 10% of the section.

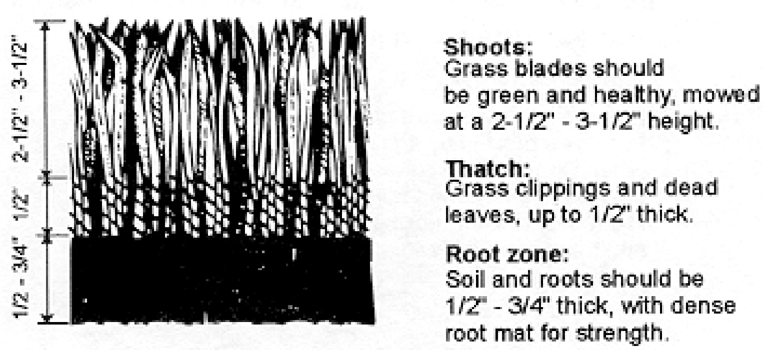
Individual pieces of sod should be cut to suppliers width and length. Maximum allowable deviation from the standard widths and lengths should be 5 percent. Broken pads or torn or uneven ends will not be accepted.

If sod is not purchased and local sod is used, cut the sod in strips 12 to 24 inches wide, 6 to 10 feet long, and approximately 1- ¼ inches thick. Roll with roots out to facilitate handling.

Sod should not be harvested or transplanted when the moisture content (excessively wet or dry) may adversely affect its survival.

Sod should be harvested, delivered, and installed within a period of 36 hours. Store rolls of sod in shade during installation. Sod not transplanted within this period should be inspected and approved prior to its installation.

Sod labels should be made available to the job foreman or inspector.



Appearance of Good Sod

Sod Placement

Rake soil surface to break crust just before laying sod. During periods of high temperature, lightly irrigate the soil immediately prior to placement. Do not install on hot, dry soil, compacted clay, frozen soil, gravel, or soil that has been treated with pesticides.

Sod strips should be laid on the contour, never up and down the slope, starting at the bottom of the slope and working up. Install strips of sod with their longest dimension perpendicular to the slope, and stagger in a brick-like pattern with snug even joints. Do not stretch or overlap. All joints should be butted tightly in order to prevent voids which would cause drying of the roots. Also, open spaces invite erosion.

On slopes greater than 3 to 1, secure sod to surface soil with wood pegs, wire staples, or split shingles (8 to 10 inches long by ¾ inch wide). The use of ladders will facilitate work on steep slopes, and prevent damage to the sod.

Wedge strips securely into place. Square the ends of each strip to provide for a close tight bond. Stagger joints at least 12 inches.

Match angled ends correctly to prevent voids. Use a knife or mason’s trowel to trim and fit irregularly shaped areas.

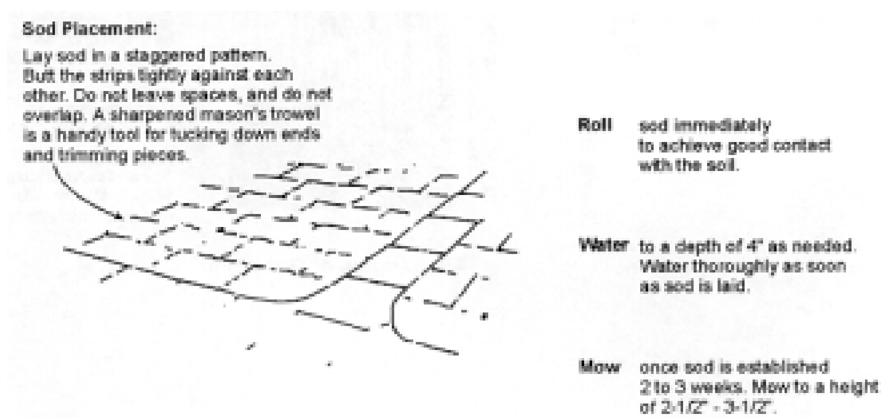
Trim all areas where water enters or leaves the sodded area so that a smooth, flush joint is secured.

Roll or tamp sod immediately following placement to insure solid contact of root mat and soil surface.

Immediately following installation, sod should be watered until moisture penetrates the soil layer beneath sod to a depth of 4 inches. Maintain optimum moisture for at least two weeks.

When sodding is carried out in alternating strips, or other patterns the areas between the sod should be seeded as soon after the sodding as possible.

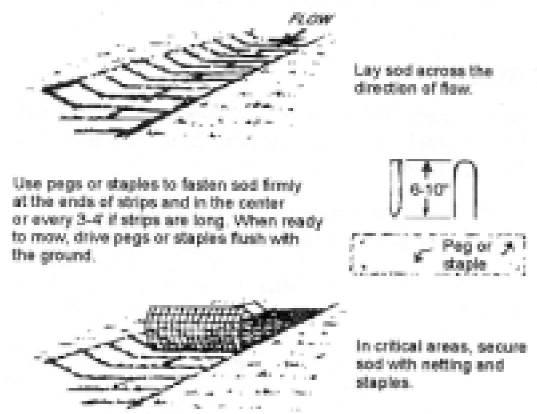
Surface water cannot always be diverted from flowing over the face of the slope, but a capping strip of heavy jute or plastic netting, properly secured, along the crown of the slope and edges will provide extra protection against lifting and undercutting of sod. The same technique can be used to anchor sod in water-carrying channels and other critical areas. Wire staples must be used to anchor netting in channel work.



Sodded Waterways

Sod provides quicker protection than seeding and may reduce the risk of early washout.

When installing sod in waterways, use the type of sod specified in the channel design.



Lay sod strips perpendicular to the direction of waterflow and stagger in a brick-like pattern. Staple firmly at the corners and middle of each strip. Jute or plastic netting may be pegged over the sod for further protection against washout during establishment.

Common Trouble Points

Sod laid on poorly prepared soil or unsuitable surface.
Grass dies because it is unable to root.
Sod not adequately irrigated after installation.
May cause root dieback; grass does not root rapidly and is subject to drying out.
Sod not anchored properly.
May be loosened by runoff.

Maintenance

Keep sod moist until it is fully rooted.
Inspect sodded areas regularly, especially after large storm events. Re-tack, re-sod, or re-seed as necessary.
Mow to a height of 2-3 inches after sod is well-rooted. Do not remove more than one-third of the shoot in any mowing.
Permanent, fine turf areas require yearly maintenance fertilization. Fertilize warm-season grass in late spring to early summer, cool-season grass in late winter and again in early fall.

References

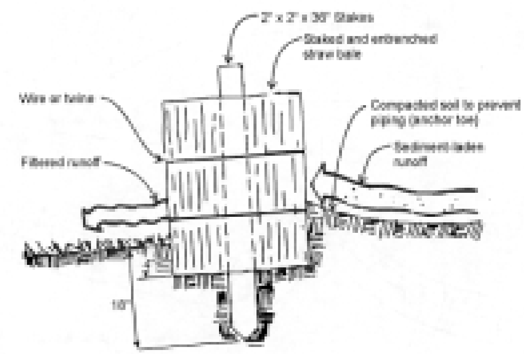
Massachusetts Department of Environmental Protection, Office of Watershed Management, Nonpoint Source Program, Massachusetts ***Nonpoint Source Management Manual***, Boston, Massachusetts, June, 1993.

North Carolina Department of Environment, Health, and Natural Resources, ***Erosion and Sediment Control Field Manual,*** Raleigh, NC, February 1991.

U.S. Environmental Protection Agency, ***Storm Water Management For Construction Activities***, EPA-832-R- 92-005, Washington, DC, September, 1992.

Straw or Hay Bale Barrier

A temporary sediment barrier consisting of a row of entrenched and anchored straw bales. Used to intercept and detain small amounts of sediment from disturbed areas of limited extent to prevent sediment from leaving the site. Decreases the velocity of sheet flows and low-to-moderate level channel flows.



Where Practice Applies

- Downslope from disturbed areas subject to sheet and rill erosion.
- In minor swales where the maximum contributing drainage area is not more than one acre.
- Where effectiveness is required for less than 3 months.

Advantages

When properly used, straw bale barriers are an inexpensive method of sediment control.

Disadvantages/Problems

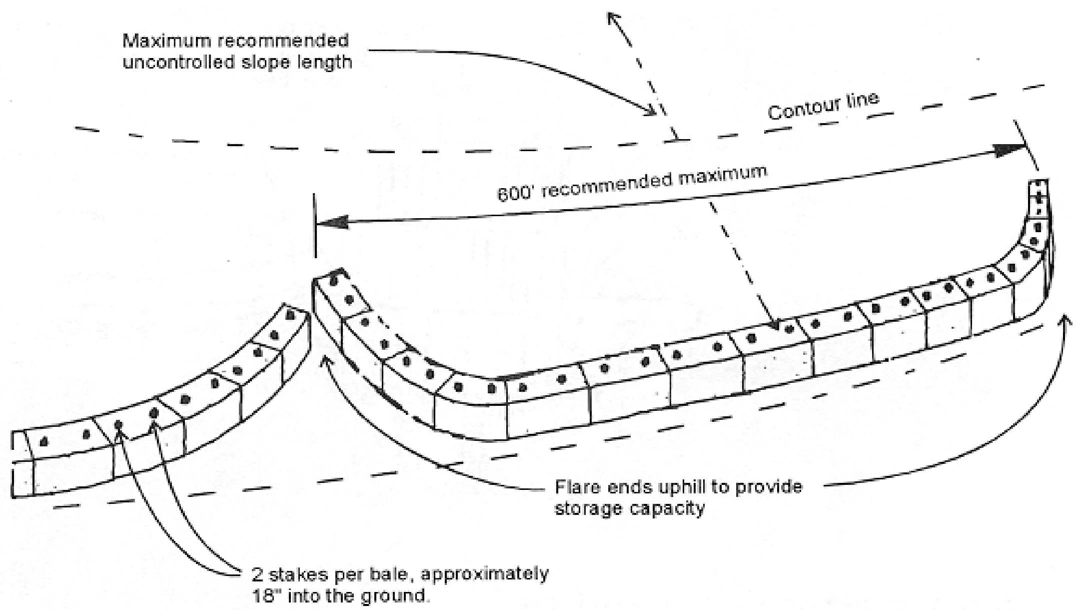
Straw bale barriers are easy to misuse. They can become contributors to a sediment problem instead of a solution unless properly located and maintained.

It is difficult to tell if bales are securely seated and snug against each other.

Planning Considerations

Straw or hay bale barriers are used similarly to sediment fence barriers; specifically where the area below the barrier is undisturbed and vegetated. Bale barriers require more maintenance than silt fence barriers and permeability through the bales is slower than sediment fence.

Bales should be located where they will trap sediment; that is, where there will be contributing runoff. Bales located along the top of a ridge serve no useful purpose, except to mark limits of a construction area. Straw or hay bales located at the upper end of a drainage area perform no sediment-collecting function.



Installation

Maximum recommended slope lengths upslope from straw or hay bale barriers are as follows:

Percent Slope	Maximum slope length, feet
1	180
4	100
9	60
14	40
18	30
30	20

(Based on providing storage for 1.0 inch of runoff.)

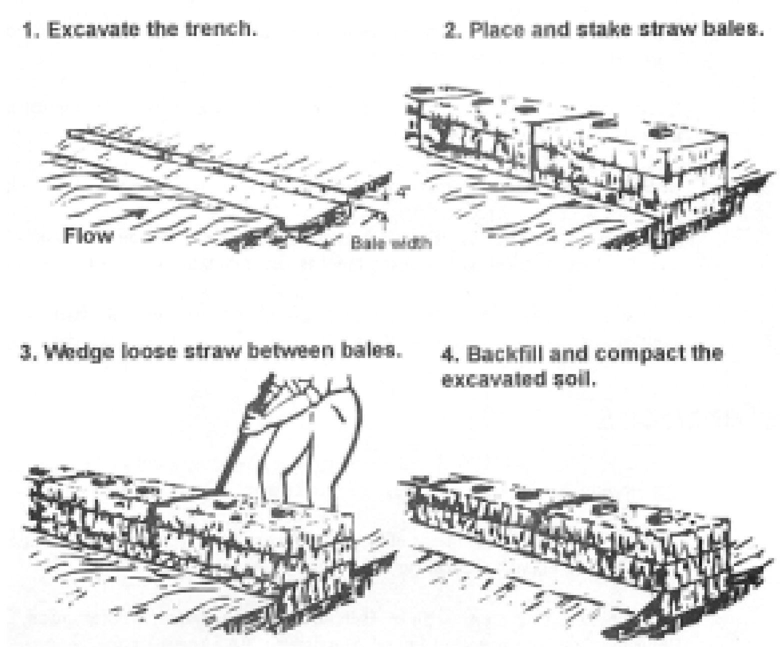
Bales should be placed in a single row, lengthwise on the contour, with ends of adjacent bales tightly abutting one another.

All bales should be either wire-bound or string-tied. Straw bales should be installed so that bindings are oriented around the sides rather than along the tops and bottoms of the bales in order to prevent deterioration of the bindings.

The barrier should be entrenched and backfilled. A trench should be excavated the width of a bale and the length of the proposed barrier to a minimum depth of 4 inches. The trench must be deep enough to remove all grass and other material which might allow underflow. After the bales are staked and chinked (filled by wedging), the excavated soil should be backfilled against the barrier. Backfill soil should conform to the ground level on the downhill side and should be built up to 4 inches against the uphill side of the barrier.

Each bale should be securely anchored by at least 2 stakes or re-bars driven through the bale. The first stake in each bale should be driven toward the previously laid bale to force the bales together. Stakes or re-bars should be driven deep enough into the ground to securely anchor the bales. For safety reasons, stakes should not extend above the bales but should be driven in flush with the top of the bale.

The gaps between the bales should be chinked (filled by wedging) with straw to prevent water from escaping between the bales. Loose straw scattered over the area immediately uphill from a straw bale barrier tends to increase barrier efficiency. Wedging must be done carefully in order not to separate the bales.



Straw bale barriers should be removed when they have served their usefulness, but not before the upslope areas have been permanently stabilized.

When used in a swale, the barrier should be extended to such a length that the bottoms of the end bales are higher in elevation than the top of the lowest middle bale to assure that sediment-laden runoff will flow either through or over the barrier but not around it.

Common Trouble Points

Improper use
Straw bale barriers have been used in streams and drainageways where high water velocities and volumes have destroyed or impaired their effectiveness.

Improper placement and installation
Staking the bales directly to the ground with no soil seal or entrenchment allows undercutting and end flow. This has resulted in additions to, rather than removal of, sediment from runoff waters.

Inadequate maintenance
Trapping efficiencies of carefully installed straw bale barriers on one project dropped from 57 percent to 16 percent in one month due to lack of maintenance.

Maintenance

Straw bale barriers should be inspected immediately after each runoff-producing rainfall and at least daily during prolonged rainfall.

Close attention should be paid to the repair of damaged bales, undercutting beneath bales, and flow around the ends of the bales.

Necessary repairs to barriers or replacement of bales should be accomplished promptly.

Sediment deposits should be checked after each runoff-producing rainfall. They must be removed when the level of deposition reaches approximately one-half the height of the barrier.

Any sediment deposits remaining in place after the straw bale barrier is no longer required should be dressed to conform to the existing grade, prepared and seeded.

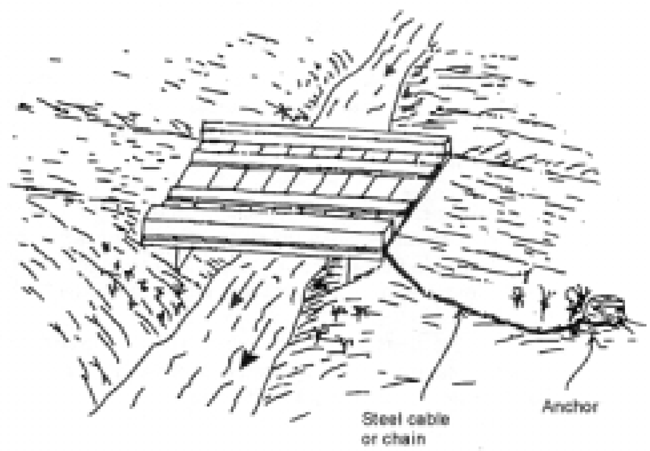
References

Minnick, E. L., and H. T. Marshall, ***Stormwater Management and Erosion Control for Urban and Developing Areas in New Hampshire***, Rockingham County Conservation District, August 1992.

Washington State Department of Ecology, ***Stormwater Management Manual for the Puget Sound Basin***, Olympia, WA, February, 1992.

Pennsylvania, Commonwealth of, Bureau of Soil and Water Conservation, ***Erosion and Sediment Pollution Control Program Manual***, Harrisburg, PA, April, 1990.

Stream Crossing, Temporary



A bridge, ford or temporary structure installed across a stream or watercourse for short-term use by construction vehicles or heavy equipment. To provide a means for construction vehicles to cross streams or watercourses without moving sediment into streams, damaging the streambed or channel, or causing flooding.

Where Practice Applies

Where heavy equipment must be moved from one side of a stream channel to another, or where light-duty construction vehicles must cross the stream channel frequently for a short period of time.

Planning Considerations

Contact the local Conservation Commission regarding any stream crossing or other work conducted in a wetland resource area. The Wetlands Protection Act requires that for any stream crossing or other work conducted in a wetland resource area, or within 100 feet of a wetland resource area, the proponent file a “Request for Determination of Applicability” or a “Notice of Intent” with the Conservation Commission.

Careful planning can minimize the need for stream crossings. Try to avoid crossing streams, whenever possible, complete the development separately on each side and leave a natural buffer zone along the stream.

Temporary stream crossings are necessary to prevent damage to stream banks and stream channels by construction vehicles crossing the stream. This reduces the sediment and other pollutants continually being tracked into the stream by vehicles. These are temporary crossings that represent channel constrictions which may cause obstruction to flow or erosion during periods of high flow. They should be in service for the shortest practical period of time and should be removed as soon as their function is complete.

Select locations for stream crossings where erosion potential is low. Evaluate stream channel conditions, overflow areas, and surface runoff control at the site before choosing the type of crossing. When practical, locate and design temporary stream crossings to serve as permanent crossings to keep stream disturbance to a minimum.

Plan stream crossings in advance of need, and when possible, construct them during dry periods to minimize stream disturbance and reduce cost. Ensure that all necessary materials and equipment are onsite before any work is begun. Complete construction in an expedient manner and stabilize the area immediately.

When construction requires dewatering of the site, construct a bypass channel before undertaking other work. If stream velocity exceeds that allowed for the inplace soil material, stabilize the bypass channel with riprap or other suitable material. After the bypass is completed and stable, the stream may be diverted.

Unlike permanent stream crossings, temporary stream crossings may be allowed to overtop during peak storm periods. The structure and approaches should, however, remain stable. Keep any fill needed in floodplains to a minimum to prevent upstream flooding and reduce erosion potential. Use riprap to protect locations subject to erosion from overflow.

Stream crossings are of three types: bridges, culverts, and fords. In selecting a stream crossing practice consider: frequency and kind of use, stream channel conditions; overflow areas; potential flood damage; and surface runoff control.

Culvert crossings

Culverts are the most common stream crossings. In many cases, they are the least costly to install, can safely support heavy loads, and are adaptable to most site conditions. Construction materials are readily available and can be salvaged. The installation and removal of culverts, however, causes considerable disturbance to the stream and surrounding area. Culverts also offer the greatest obstruction to flood flows and, therefore, are subject to blockage and washout.

Bridges

Where available materials and designs are adequate to bear the expected loadings, bridges are preferred for temporary stream crossing.

Bridges usually cause the least disturbance to the stream bed, banks, and surrounding area. They provide the least obstruction to flow and fish migration. They generally require little or no maintenance, can be designed to fit most site conditions, and can be easily removed and materials salvaged. Bridges, however, are generally the most expensive to design and construct. Also, they present a safety hazard if not adequately designed, installed, and maintained. If washed out, they cause a longer construction delay and are more costly to repair.

In steep watersheds it is recommended to tie a cable or chain to one corner of the bridge frame with the other end secured to a large tree or other substantial object. This will prevent flood flows from carrying the bridge downstream where it may cause damage to property.

Fords

Fords should only be used where crossings are infrequent.

Fords made of stabilizing material such as rock are sometimes used in steep areas subject to flash flooding, where normal flow is shallow (less than 3 inches deep) or intermittent. Fords are especially adapted for crossing wide, shallow watercourses.

When properly installed, fords offer little or no obstruction to flow, can safely handle heavy loadings, are relatively easy to install and maintain, and, in most cases, may be left in place at the end of construction.

Potential problems include:

Approach sections are subject to erosion. Do not use fords where bank height exceeds 5 feet.

Excavation for the installation of the riprap-gravel bottom and filter material causes major stream disturbance. In some cases, fords may be adequately constructed by shallow filling without excavation.

The stabilizing material is subject to washing out during storm flows and may require replacement.

Mud and other contaminants are brought directly into the stream on vehicles unless crossings are limited to no-flow conditions.

Design and Construction Recommendations

A stream crossing must be non-erosive and structurally stable, and must not introduce any flooding or safety hazard. Bridge design in particular should be undertaken only by a qualified engineer. The following standards apply only to erosion and sediment control aspects of bridges, culverts, and fords.

The anticipated life of a temporary stream crossing structure is usually considered to be 1 year or less. Remove the structure immediately after it is no longer needed.

As a minimum, design the structure to pass bank-full flow or peak flow, whichever is less, from a 2-year frequency, 24-hour duration storm without over topping. Ensure that no erosion will result from the 10-year peak storm.

Ensure that design flow velocity at the outlet of the crossing structure is nonerosive for the stream channel.

Consider overflow for storms larger than the design storm and provide a protected overflow area.

Planning and Site Preparation

Construct crossing when stream flow is low. Have all necessary materials and equipment on site before work begins.

Minimize clearing and excavation of streambanks, bed, and approach sections. Plan work to minimize crossing the stream with equipment. If possible, complete all work on one side of the stream before crossing to work on other side.

Location

The temporary crossing should be located where there will be the least disturbance to the stream channel, the stream banks, the flood plain adjacent to the channel, and adjacent wetlands.

Width

The minimum road width of a temporary crossing should be 12 feet.

Alignment

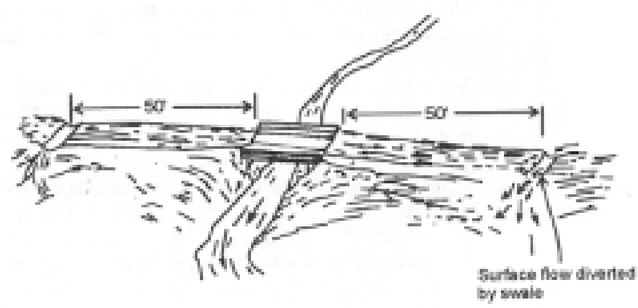
The temporary crossing should be at right angles to the stream whenever possible. If the approach conditions to the crossing are such that a perpendicular crossing is not possible, then a variation of up to 15 degrees is allowable.

Approaches

The centerline of the roadway approaches to the crossing should coincide with the crossing alignment for a distance of 30 feet in either direction. The maximum height of fill associated with the approaches should not exceed 2 feet. Limit surface runoff by installing diversions.

Surface Water and High Flow Diversion

A water diversion structure such as a swale should be constructed across the roadway at the end of both approaches to the crossing to allow stream flow exceeding the design storm to pass safely around the structure. These swales will also prevent surface water from flowing along the roadway and directly into the stream.



Locate swales not more than 50 feet from the waterway crossing. This will prevent roadway surface runoff from directly entering the waterway. The 50 feet is measured from the top of the waterway bank. If the roadway approach is constructed with a reverse grade away from the waterway, a separate diverting structure is not required.

Temporary Stream Diversion

Avoid diverting stream out of its natural channel by working on one-half of the installation at a time. If stream must be diverted, select most appropriate location considering extent of clearing, channel grade, amount of cut, and spoil disposal.

Excavate diversion channel starting at the lower end. If stream velocity exceeds that allowable for the temporary channel, stabilize with riprap. Temporary bypass channel must be stable for flows up to and including the 10-year storm.

The crossing site should be built in the dry streambed and stabilized before the stream is redirected to its normal course.

Sediment Traps

Where appropriate, install instream sediment traps immediately below stream crossings to reduce downstream sedimentation. Install before excavating or grading the approaches to a ford.

Excavate trap at least 2 feet below stream bottom and approximately twice the channel width for a minimum distance equal to one-half the length of crossing. Remove all spoil to an area outside the flood plain. Stabilize spoil appropriately.

Ensure that the flow velocity through the basin does not exceed the allowable flow velocity for the inplace soil material; otherwise it should not be excavated. In locations where trees or other vegetation must be removed, the sediment trap may be more damaging to the stream than if it were not installed.

Bridges and Culverts

Elevate bridge abutments or culvert fill 1 foot minimum above the adjoining streambank to allow storm overflow to bypass structure without damage. Culvert pipe should extend well beyond fill side slopes.

Protect disturbed streambanks, fill slopes and overflow areas with riprap or other suitable methods. Stabilize other disturbed areas as specified in the vegetation plan. Good surface stabilization is especially important at stream crossings as all eroded material directly enters the stream.

Earth fill for approaches should be free of roots, woody vegetation, oversized stones, organic material or other objectionable materials. The fill should be compacted by routing construction equipment over the fill so that the entire area of the fill is transversed by at least one wheel track or tread track of the equipment.

Bridges

A temporary bridge should be constructed at or above the stream bank elevation. Excavation of the stream bank should not be allowed for construction of this practice.

Span

Bridges should be constructed to span the entire width of the channel. If the width of the channel as measured from top of bank to top of bank exceeds 8 feet, then a footing, pier, or bridge support may be constructed in the stream bed. An additional footing or support will be allowed for each additional 8 feet of channel width. No footing, pier, or bridge support should be used in the stream bed for channel widths less than 8 feet.

Materials

Materials should be of sufficient strength to support the anticipated design loads. Stringers may be logs, sawn timber, prestressed concrete beams, or other appropriate materials. Decking materials must be butted tightly and securely fastened to the stringers to prevent soil, and other construction materials from falling into the stream channel below.

Bridge Anchors

The bridge should be anchored at only one end with either a steel cable or chain to prevent the bridge from floating away during flood events. The anchoring should be sufficient to prevent the bridge from floating downstream and possibly causing an obstruction in the stream channel below. Acceptable anchors are large trees, large boulders, or driven steel anchors.

Culverts

The minimum size for a culvert should be 18 inches. The maximum size for a culvert should be the largest pipe diameter that will fit into the existing channel without a significant amount of excavation required for its placement. Culverts may be circular or elliptical depending on the site requirements. Culverts should extend a minimum of one foot beyond the upstream and downstream toe of backfill placed around the culvert. Length should not exceed 40 feet.

Filter Cloth

Place filter cloth on the stream bed and the stream banks before installing the culvert and backfill. The filter cloth should extend a minimum of six inches and a maximum of one foot past the toe of the backfill.

Culvert Placement

The culvert should be installed on the natural stream bed grade. No overfall should be permitted at the downstream invert.

Backfill

No earth or fine-grained soil backfill should be used for temporary culvert crossings. Backfill should be clean, coarse aggregate. The backfill should be placed in maximum 6 inch lifts and compacted using a vibrating plate compactor. Material should be hand compacted around the haunches of the pipe, using particular care to assure that the line and grade of the pipe is maintained. The minimum allowable backfill over the pipe should be 12 inches or one-half pipe diameter which ever is greater. If multiple culverts are used they should be separated by a minimum of 12 inches of compacted aggregate backfill.

Appropriate headwalls or large rock should be placed on the upstream and downstream ends of the temporary fill crossing to protect against erosion during large flood flows.

Fords

Install geotextile fabric in channel to stabilize foundation, then apply well-graded, weather-resistant stone (3 to 6 inch) over fabric. Use only stabilization fabric, not filter fabric.

Stabilization

All areas disturbed by the installation of the temporary crossing should be stabilized using either rock, gravel, or vegetation as appropriate.

Removal

Remove temporary stream crossings as soon as they are no longer needed. Restore stream channel to original cross section and stabilize all disturbed areas. Appropriate measures should be taken to minimize effects on water quality when removing the crossing. Fords may be left in place if site conditions allow.

Temporary bypass channels should be permanently stabilized or removed. If removed, overfill by at least 10%, compact, and stabilize appropriately.

Leave in-stream sediment traps in place.

Common Trouble Points

Inadequate flow capacity and/or lack of overflow area around structure
Results in washout of culverts or bridge abutments.

Inadequate stabilization of overflow area
Results in severe erosion around bridges and culverts.

Exit velocity from culvert or bridges too high
Causes stream channel erosion and may eventually cause erosion of bridge or culvert fill.

Debris not removed after a storm
Clogging may cause washout of culverts or bridges.

Inadequate compaction under or around culvert pipes
Culverts wash out due to seepage and piping.

Stone size too small
Ford washes out.

Culvert pipes too short
Results in a crossing supported by steep, unstable fill slopes.

Maintenance

Inspect temporary crossing after each rainfall event for accumulation of debris, blockage, erosion of abutments and overflow areas, channel scour, riprap displacement, or piping along culverts.

Remove debris; repair and reinforce damaged areas immediately to prevent further damage to the installation.

Remove temporary stream crossings immediately when they are no longer needed. Restore the stream channel to its original cross-section, and smooth and stabilize all disturbed areas.

Leave in-stream sediment traps in place to continue capturing sediment.

References

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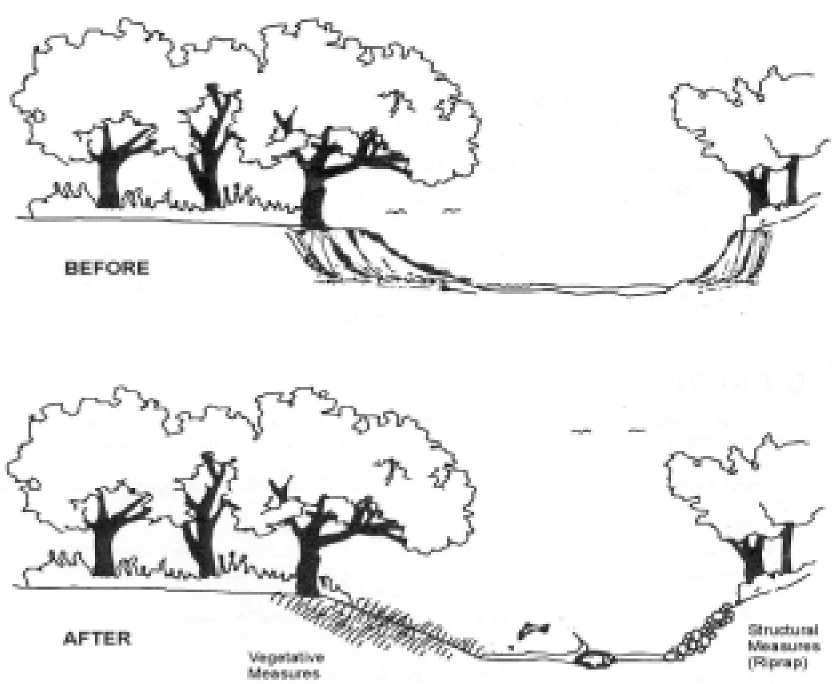
North Carolina Sediment Control Commission, ***Erosion and Sediment Control Planning and Design Manual,*** Raleigh, NC, September, 1988.

Streambank Protection and Stabilization

Protecting and stabilizing banks of streams or excavated channels against scour and erosion. This practice may be accomplished by structural or vegetative means, or by a combination of both.



Purpose

- To protect streambanks from the erosive forces of moving water.
- To prevent the loss of land or damage to utilities, roads, buildings, or other adjacent facilities.
- To maintain the capacity of the channel.
- To control channel meander which would adversely affect downstream facilities.
- To reduce sediment loads causing downstream damages and pollution.
- To improve the stream for recreational use or as a habitat for fish and wildlife.

Where Practice Applies

This practice applies to natural or excavated channels where the streambanks are susceptible to erosion from the action of water, ice, or debris; excessive runoff from construction activities; or to damage from vehicular traffic.

This practice also applies to controlling erosion on shorelines where the problem can be solved with relatively simple structural measures, vegetation, or upland erosion control practices.

Advantages

Structural Methods

- Streambank protection can break wave action and reduce the velocity of flood flows.
- The reduction of velocity can lead to the deposit of water-borne soil particles.
- Water quality benefits of reduced erosion and downstream siltation.

Vegetative and Bioengineering Methods

Vegetative and bioengineering stabilization methods have additional advantages:

- Vegetative techniques are generally less costly and more compatible with natural stream characteristics.
- Roots and rhizomes stabilize streambanks.
- Certain reeds and bulrushes have the capability of improving water quality by absorbing certain pollutants such as heavy metals, detergents, etc.
- Plants regenerate themselves and adapt to changing natural situations, thus offering a distinct economic advantage over mechanical stabilization.
- Mechanical materials provide for interim and immediate stabilization until vegetation takes over.
- Once established, vegetation can outlast mechanical structures and requires little maintenance while regenerating itself
- Aesthetic benefits and improved wildlife and fisheries habitat.

Disadvantages/Problems

Structural Methods

- Cost of structural practices.
- Aesthetics.

Vegetative Methods

- Native plants may not be carried by regular nurseries and may need to be collected by hand, or obtained from specialty nurseries. Nurseries which carry these plants may require a long lead time for large orders.
- Flow retarding aspects of vegetated waterways need to be taken into account.
- Structural practices can be installed on steeper slopes than vegetative methods.
- Will not withstand as high flow velocities as structural methods.

Planning Considerations

Contact the local Conservation Commission regarding any stream crossing or other work conducted in a wetland resource area. The Wetlands Protection Act requires that for any stream crossing or other work conducted in a wetland resource area, or within 100 feet of a wetland resource area, the proponent file a "Determination of Applicability" or a "Notice of Intent" with the Conservation Commission.

Stream channel erosion problems vary widely in type and scale, and there is no one measure that works in all cases. Stabilization structures should be planned and designed by an engineer with experience in this field. Many of the practices involve the use of manufactured products and should be installed in accordance with the manufacturers specifications. Where long reaches of stream channels require stabilization, make detailed strewn studies.

Before selecting a structural stabilization technique, the designer should carefully evaluate the possibility of using vegetative stabilization in conjunction with structural measures to achieve the desired protection. Vegetative techniques are generally less costly and more compatible with natural stream characteristics.

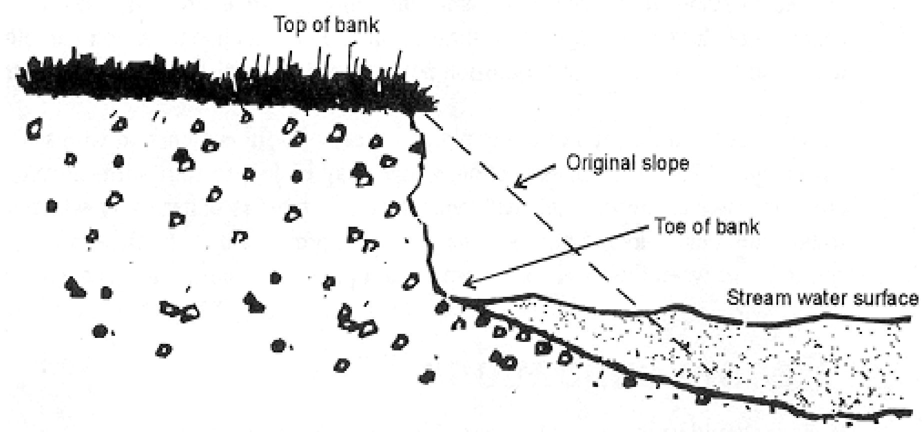
Wherever possible, it is best to protect banks with living plants that are adapted to the site. Natural plant communities are aesthetically pleasing, provide a habitat for fish and wildlife, afford a self-maintaining cover, and are less expensive and damaging to the environment.

Special attention should be given to the preservation of fish and wildlife habitat, and trees of significant value for wildlife food or shelter, or for aesthetic purposes. Wildlife habitat can be improved by using woody plants and grasses that provide food and/or cover for native wildlife species. The retention of a 30-foot riparian zone along stream channels that is established to trees, shrubs, or grasses may provide wildlife, landscaping and water quality benefits.

Where construction will adversely affect a significant fish or wildlife habitat, mitigation measures should be included in the plan. Mitigation measures may include pools, riffles, flats, cascades, or other similar provisions.

Upstream development accelerates streambank erosion by increasing the velocity, frequency, and duration of flow. As a result, many natural streams that were stable become unstable following urbanization.

Most natural stream channels have bank-full capacity to pass the runoff from a 2-year recurrence interval storm. In a typical urbanizing watershed, however, stream channels may become subject to a 3 to 5 times as many bank-full flows if stormwater runoff is not properly managed. Stream channels that were once parabolic in shape and covered with vegetation may be transformed into wide rectangular channels with barren banks.



The following is a partial list of elements which may be involved in a plan for streambank protection.

- **Obstruction removal** - The removal of fallen trees, stumps, debris, minor ledge outcroppings and sand and gravel bars that may cause water turbulence and deflection, causing erosion of the bank.
- **Clearing** - The removal of trees and brush which adversely affect the growth of desirable bank vegetation.
- **Bank sloping** - The reduction of the slope of streambanks. Consideration should be given to flattening the side slope of the channel in some reaches to facilitate the establishment of vegetation or for the installation of structural bank protection.
- **Fencing** - Artificial obstructions to protect vegetation needed for streambank protection or to protect critical areas from damage from stock trails or vehicular traffic.
- **Vegetation** - Vegetative streambank stabilization is generally applicable where bankfull flow velocity does not exceed 6 feet/second and soils are erosion-resistant. Above 6 feet/second, structural measures are generally required.

- **Riprap** - Heavy angular stone placed on the streambank to provide armor protection against erosion.
- **Jetties** - Deflectors constructed of posts, piling, fencing rock, brush other materials which project into the stream to protect banks at curves and reaches subjected to impingement by high velocity currents.
- **Revetments** - Pervious or impervious structures built on or parallel to the stream to prevent scouring streamflow velocities adjacent to the streambank.
- **Bioengineering** - Bioengineering utilizes live plant parts in combination with structural methods to provide soil reinforcement and prevent surface erosion.

Structural measures, when employed correctly, immediately ensure satisfactory protection of stream banks. Structures are expensive to build, however, and to maintain. Without constant upkeep, they are exposed to progressive deterioration by natural agents. The materials used may prevent reestablishment of native plants and animals. Often structural measures destroy the appearance of the stream. Also, structural stabilization and channelization can alter the hydrodynamics of a stream and transfer erosion potential and associated problems downstream.

In contrast, the utilization of living plants instead of or in conjunction with structures has many advantages. The degree of protection, which may be low to start with, increases as the plants grow and spread. Repair and maintenance of structures is unnecessary where self-maintaining streambank plants are established. The protection provided by natural vegetation is more reliable and effective when the cover consists of natural plant communities adapted to their site.

Design Recommendations

Designs should be developed in accordance with the following principles:

- The grade must be controlled, either by natural or artificial means, before any permanent type of bank protection can be considered feasible; unless the protection can be safely and economically constructed to a depth well below the anticipated lowest depth of bottom scour.
- Streambank protection should be started at a stabilized or controlled point and ended at a stabilized or controlled point on the stream.
- Make protective measures compatible with other channel modifications planned or being carried out in other channel reaches.
- Ensure that the channel bottom is stable or stabilized by structural means before installing any permanent bank protection.
- Channel clearing, if needed to remove stumps, fallen trees, debris and bars which force the streamflow into the streambank, should be an initial element of the work.
- Changes in channel alignment should be made only after an evaluation of the effect on the land use, interdependent water disposal systems, hydraulic characteristics, and existing structures.

- Measures must be effective for the minimum design velocity of the peak discharge of the 10-year storm and be able to withstand greater floods without serious damage.
- Vegetative protection should be considered on the upper portions of eroding banks and especially on those areas which are subject to infrequent inundation.
- Stabilize all areas disturbed by construction as soon as complete.

Vegetative Methods

Channel reaches are often made stable by establishing vegetation where erosion potential is low and installing structural measures where the attack is more severe, such as the outside of channel bends and where the natural grade steepens. Vegetative methods must be effective for the design flow.

Bank reshaping and disturbance should be kept to a minimum except as necessary to install the practice. Where this is needed, banks should be shaped to result in a bank slope of 1:1 or flatter.

A temporary seeding should be used on all sites to provide protection while the permanent cover is becoming established.

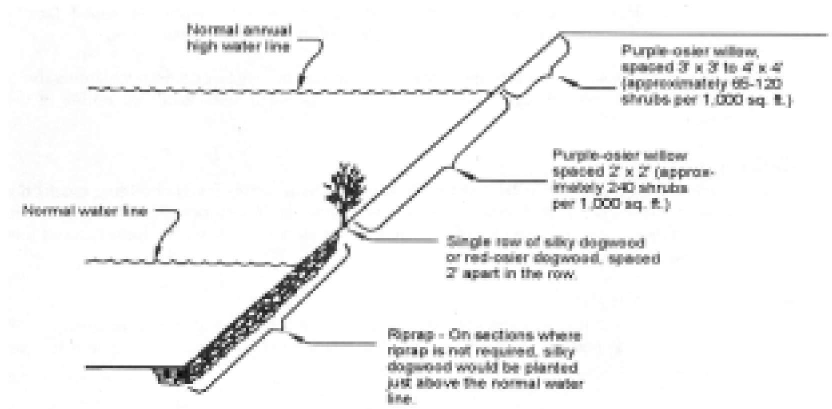
Streambanks to be protected using grasses may need to be shaped on a 2:1 or 3:1 slope to provide for adequate seedbed preparation. The use of sod, instead of seeding, should be evaluated where economically justified and technically feasible.

The type of vegetative cover to be used should be based on the soil type, stream velocities, adjacent land use and anticipated level of maintenance to be performed.

A maintenance program should be established to provide sufficient moisture, fertility, replacement of dead or damaged plants and protection from damage by insects, diseases, machinery and human activities.

Streambanks stabilized using grasses should be evaluated as to whether an occasional or periodic mowing and fertilization are to be performed to maintain a healthy protective ground cover.

Sites should be protected from damage by vehicular and human traffic for the length of time necessary to get vegetative cover well established, but no less than one full growing season.



Staking

This involves inserting and tamping live, rootable vegetative cuttings into the ground. If correctly prepared and placed, the live stake will root and grow.

Dormant Woody Plantings

This is planting live, dormant-stem cuttings of woody plant species ½ to 3 inches or more in diameter.

Grasses

Where a good seedbed can be prepared, and on smaller streams where flow velocities are less, it may be feasible to stabilize eroding streambanks by seeding grasses above or in combination with dormant woody plantings. See recommendations in **Permanent Seeding** and in the supplementary material in Part 4.

A temporary seeding or mulching should be completed on those sites where a permanent seeding will not be established within 30 days following installation of a project. See **Temporary Seeding**.

Structural Methods

Generally applicable where flow velocities exceed 6 feet/second or where vegetative streambank protection is inappropriate.

Since each reach of channel requiring protection is unique, measures for structural streambank protection should be installed according to a plan based on specific site conditions.

Riprap

Riprap is the most common structural method used, but other methods such as gabions, deflectors, reinforced concrete, log cribbing, and grid pavers should be considered, depending on site conditions.

When possible, slope banks to 2:1 or flatter, and place a gravel filter or filter fabric on the smoothed slopes before installing riprap. Place the toe of the riprap at least 1 foot below the stream channel bottom or below the anticipated depth of channel degradation.

It is important to extend the upstream and downstream edges of riprap well into the bank and bottom. Extend riprap sections the entire length between well-stabilized points of the stream channel.

Gabions

These rectangular, rock-filled wire baskets are pervious, semi-flexible building blocks that can be used to armor the bed and/or banks of channels or act as deflectors to divert flow away from eroding channel sections. Design and install gabions in accordance with manufacturer's standards and specifications.

Reinforced concrete

May be used to armor eroding sections of the streambank by constructing retaining walls or bulk heads. Provide positive drainage behind these structures. Reinforced concrete may also be used as a channel lining for stream stabilization.

Log Cribbing

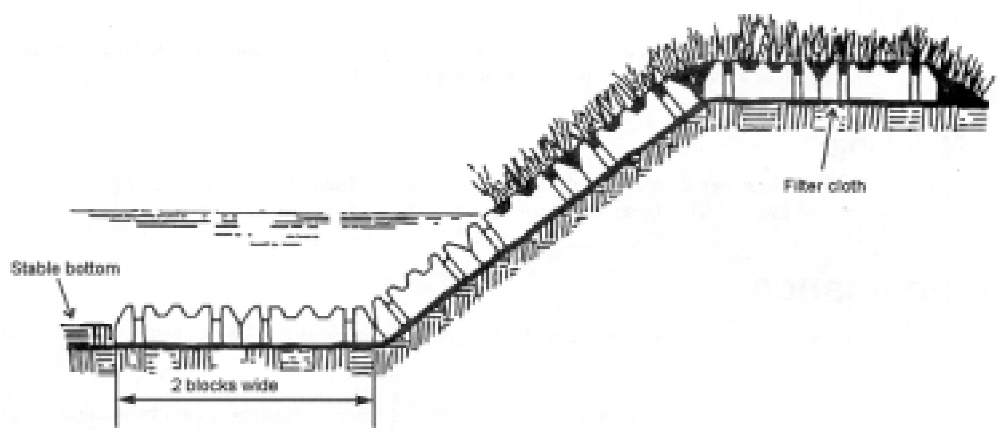
Retaining structure built of logs to protect streambanks from erosion. Vegetation can be planted between logs.

Grid pavers

Modular concrete units with interspersed void areas that can be used to armor the streambank while maintaining porosity and allowing the establishment of vegetation. These structures may be obtained in precast blocks or mats that come in a variety of shapes, or they may be formed and poured in place. Design and install in accordance with manufacturer's instructions.

Revetment

Structural support or armoring to protect an embankment from erosion. Riprap or gabions are commonly used. Gabions may be either stacked or placed as a mattress. Install revetment to a depth below the anticipated channel degradation and into the channel bed as necessary to provide stability.



Bioengineering Methods

Bioengineering combines structural and vegetative methods.

Streams in urban settings may carry an increase in runoff of such great magnitude that they cannot be maintained in a natural state. Soil bioengineering methods can provide for stabilization without complete visual degradation and higher effectiveness than purely mechanical techniques.

See Part 4 for descriptions of bioengineering methods and practices.

Construction Recommendations

Where possible: trees should be left standing; brush and stumps not removed; and construction operations carried on from one side, leaving vegetation on the opposite side.

Spoil resulting from excavation and shaping should be leveled or removed to permit free entry of water from adjacent land surface without excessive erosion or harmful ponding.

Trees and other fallen natural vegetation that do not deter stream flow should be left for fish habitat.

Vegetation should be established on all disturbed areas immediately after construction, weather permitting. If weather conditions are such as to cause a delay in the establishment of vegetation, the area should be mulched.

Topsoil

When soil conditions are particularly adverse for herbaceous vegetation, topsoil should be spread to a depth of 4 inches or more on critical areas to be seeded or sodded.

Mulching

Seeded side slopes should be mulched. Where streambanks are steeper than 2:1 or higher than 10 feet, the mulch should be anchored with paper twine fabric or equivalent material.

Maintenance

Check after every high-water event. Repairs should be made as quickly as possible after the problem occurs.

All temporary and permanent erosion and sediment control practices should be maintained and repaired as needed to assure continued performance of their intended function.

Streambanks are always vulnerable to new damage. Repairs are needed periodically. Banks should be checked after every high-water event is over. Gaps in the vegetative cover should be fixed at once with new plants, and mulched if necessary. Fresh cuttings from other plants on the bank can be used, or they can be taken from mother-stock plantings if they are available.

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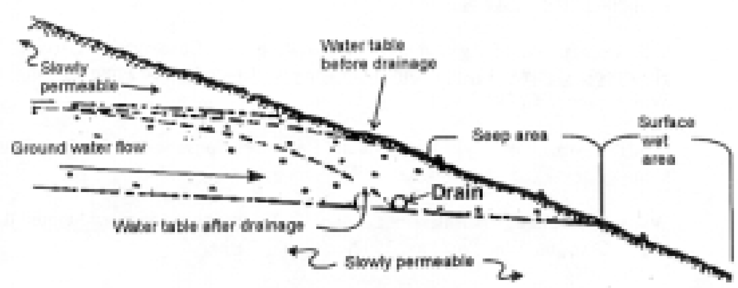
Washington State Department of Ecology, ***Stormwater Management Manual for the Puget Sound Basin***, Olympia, WA, February, 1992.

Subsurface Drain

A perforated conduit such as a pipe, tubing, or tile installed beneath the ground to intercept, collect, and convey excess ground water to a satisfactory outlet.



Purpose

- To provide a dewatering mechanism for draining excessively wet soils.
- To improve soil and water conditions for vegetative growth.
- To prevent sloughing of steep slopes due to ground water seepage.
- To improve stability of structures with shallow foundations by lowering the water table.

Where Practice Applies

Wherever excessive water must be removed from the soil.

The soil should have depth and sufficient permeability to permit installation of an effective drainage system at a depth of 2 to 6 feet.

An adequate outlet for the drainage system must be available either by gravity or by pumping. The quantity and quality of discharge should not damage the receiving stream.

Advantages

- An effective way to lower the water table.
- Subsurface drains often provide the only practical method of stabilizing excessively wet, sloping soils.

Disadvantages/Problems

Problems may be encountered with tree roots.

Planning Considerations

Contact the local Conservation Commission regarding any work conducted in a wetland resource area. The Wetlands Protection Act requires that for work conducted in a wetland resource area, or within 100 feet of a wetland resource area, the proponent file a "Request for Determination of Applicability" or a "Notice of Intent" with the Conservation Commission.

Subsurface drains usually consists of perforated, flexible conduit installed in a trench at a designed depth and grade. The trench around the conduit is often backfilled with a sand-gravel filter or gravel envelope. Backfill over the drain should be an open, granular soil of high permeability.

Subsurface drainage systems are of two types; relief drains and interceptor drains. Relief drains are used either to lower the water table in order to improve the growth of vegetation, or to remove surface water. They are installed along a slope and drain in the direction of the slope. They can be installed in a gridiron pattern, a herringbone pattern, or a random pattern.

Interceptor drains are used to remove water as it seeps down a slope to prevent the soil from becoming saturated and subject to slippage. They are installed across a slope and drain to the side of the slope. They usually consist of a single pipe or series of single pipes instead of a patterned layout.

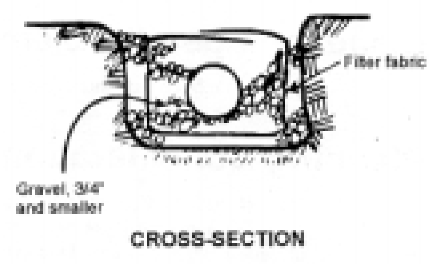
Design Recommendations

Subsurface drain should be sized for the required capacity. Design charts are available in Natural Resources Conservation Service references and from other sources. Manufacturers of special purpose drain configurations can provide instructions for design.

The minimum velocity required to prevent silting is 1.4 feet per second. The line should be installed on a grade to achieve at least this velocity.

The outlet of the subsurface drain should empty into a receiving channel, swale, or stable vegetated area adequately protected from erosion and undermining.

Construction Recommendations



The trench should be constructed on continuous grade with no reverse grades or low spots.

Soft or yielding soils under the drain should be stabilized with gravel or other suitable material.

Deformed, warped, or otherwise unsuitable pipe should not be used.

A sand-gravel filter at least three inches thick should be placed all around the pipe. Manufactured filters designed for the purpose, such as filter fabric, may be used as alternatives.

The trench should be backfilled immediately after placement of the pipe. No sections of pipe should remain uncovered overnight or during a rainstorm. Backfill material should be placed in the trench in such a manner that the drain pipe is not displaced or damaged.

Maintenance

Subsurface drains should be checked periodically to ensure that they are freeflowing and not clogged with sediment.

The outlet should be kept clean and free of debris.

Surface inlets should be kept open and free of sediment and other debris.

Trees located too close to a subsurface drain often clog the system with their roots. If a drain becomes clogged, relocate the drain or remove the trees as a last resort. Drain placement should be planned to minimize this problem.

Where drains are crossed by heavy vehicles, the line should be checked to ensure that it is not crushed.

References

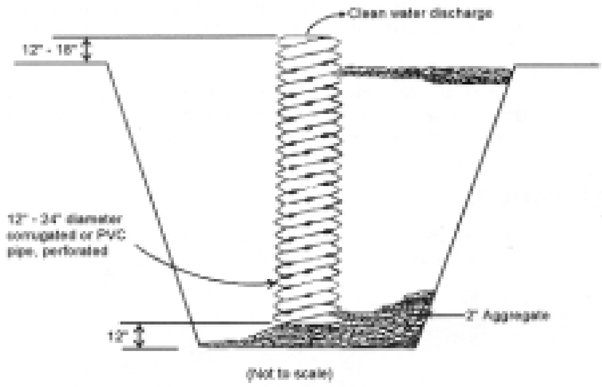
Massachusetts Department of Environmental Protection, Office of Watershed Management, Nonpoint Source Program, ***Massachusetts Nonpoint Source Management Manual***, Boston, Massachusetts, June, 1993.

U.S. Environmental Protection Agency, S***torm Water Management For Construction Activities*** EPA-832-R- 92-005, Washington, DC, September, 1992.

Washington State Department of Ecology, ***Stormwater Management Manual for the Puget Sound Basin***, Olympia, WA, February, 1992.

Sump Pit

A temporary pit which is constructed to trap and filter water for pumping into a suitable discharge area. A perforated vertical standpipe is placed in the center of the pit to collect filtered water. The purpose of this practice is to remove excessive water in a manner that improves the quality of the water.



Where Practice Applies

Sump pits are constructed when water collects during the excavation phase of construction. This practice is particularly useful in urban areas during excavation for building foundations.

Planning Considerations

Discharge of water pumped from the standpipe should be to a suitable practice such as a sediment basin, sediment trap, or a stabilized area.

If water from the sump pit will be pumped directly to a storm drainage system, geotextile filter fabric should be wrapped around the standpipe to ensure clean water discharge. It is recommended that ¼ to ½ inch mesh hardware cloth wire be wrapped around and secured to the standpipe prior to attaching the filter fabric. This will increase the rate of water seepage into the standpipe.

Design Recommendations

A perforated vertical standpipe is placed in the center of the pit to collect filtered water. The standpipe will be a perforated 12 to 24-inch diameter corrugated metal or PVC plastic pipe. Water is then pumped from the pit to a suitable discharge area. The pit will be filled with coarse aggregate.

Maintenance

The sump pit will become clogged with sediment, oils, and organic matter over time. It is important to remove grass clippings and leaves from the surface of the aggregate in order to prolong its life.

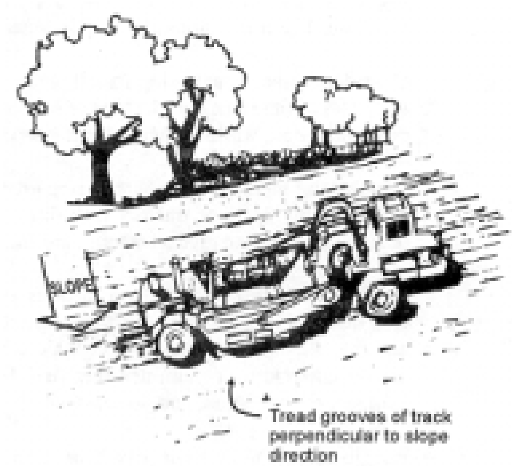
The pit should be checked after every major storm to evaluate its effectiveness. If the pit and filter fabric become plugged with sediment, the pit should be rehabilitated. In some cases complete removal and replacement of the entire dry well may be necessary.

References

U.S. Department of Agriculture, Natural Resources Conservation Service, Champaign, IL, Urban Conservation Practice Standards, 1994.

Surface Roughening

Roughening a bare soil surface with horizontal grooves running across the slope, stair stepping, or tracking with construction equipment; or by leaving slopes in a roughened condition by not fine grading them.



HEAVY EQUIPMENT CAN BE USED TO MECHANICALLY SCARIFY SLOPES

Purpose

To aid the establishment of vegetative cover from seed, to reduce runoff velocity and increase infiltration, and to reduce erosion and provide for sediment trapping.

Where Practice Applies

All construction slopes require surface roughening to facilitate stabilization with vegetation, particularly slopes steeper than 3:1. This practice should also be done prior to forecasted storm events and before leaving a job site for a weekend.

Advantages

Surface roughening provides some instant erosion protection on bare soil while vegetative cover is being established.

It is an inexpensive and simple erosion control measure.

Disadvantages/Problems

While this is a cheap and simple method of erosion control, it is of limited effectiveness in anything more than a moderate storm.

Surface roughening is a temporary measure. If roughening is washed away in a heavy storm, the surface will have to be re-roughened and new seed laid.

Planning Considerations

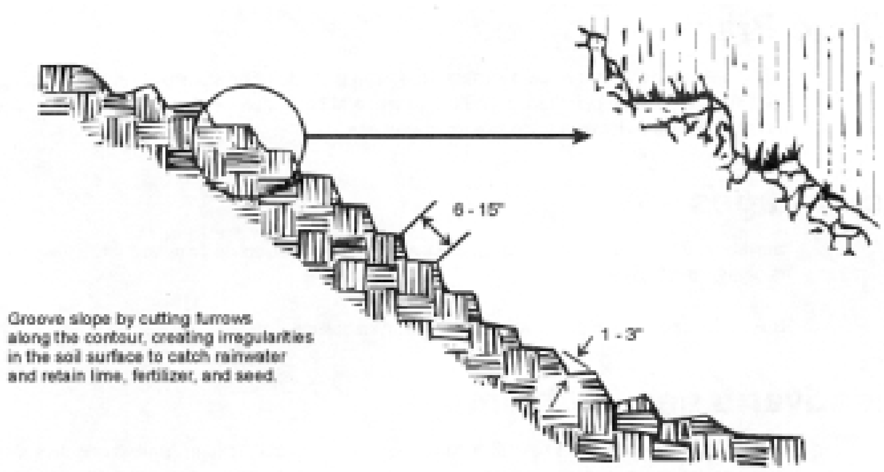
Roughening a sloping bare soil surface with horizontal depressions helps control erosion by aiding the establishment of vegetative cover with seed, reducing runoff velocity, and increasing infiltration. The depressions also trap sediment on the face of the slope.

Consider surface roughening for all slopes. The amount of roughening required depends on the steepness of the slope and the type of soil. Stable, sloping rocky faces may not require roughening or stabilization, while erodible slopes steeper than 3:1 require special surface roughening.

Roughening methods include stair-step grading, grooving, and tracking. Equipment such as bulldozers with rippers or tractors with disks may be used. The final face of slopes should not be bladed or scraped to give a smooth hard finish.

Graded areas with smooth, hard surfaces give a false impression of “finished grading” and a job well done. It is difficult to establish vegetation on such surfaces due to reduced water infiltration and the potential for erosion. Rough slope surfaces with uneven soil and rocks left in place may appear unattractive or unfinished at first, but they encourage water infiltration, speed the establishment of vegetation, and decrease runoff velocity.

Rough, loose soil surfaces give lime, fertilizer, and seed some natural coverage. Niches in the surface provide microclimates which generally provide a cooler and more favorable moisture level than hard flat surfaces; this aids seed germination.



Construction Recommendations

Roughening methods include stair-step grading, grooving, and tracking. Factors to be considered in choosing a method are slope steepness, mowing requirements, and whether the slope is formed by cutting or filling.

Graded areas with slopes greater than 3:1 but less than 2:1 should be roughened before seeding. This can be accomplished in a variety of ways, including "track walking," or driving a crawler tractor up and down the slope, leaving a pattern of cleat imprints parallel to slope contours.

Graded areas steeper than 2:1 should be stair-stepped with benches. The stair-stepping will help vegetation become established and also trap soil eroded from the slopes above.

Disturbed areas which will not require mowing may be stair-step graded, grooved, or left rough after filling.

Stair-step grading is appropriate for soils containing large amounts of soft rock. Each "step" catches material that sloughes from above, and provides a level site where vegetation can become established. Stairs should be wide enough to work with standard earth moving equipment.

Areas which will be mowed (these areas should have slopes less steep than 3:1) may have small furrows left by disking, harrowing, raking, or seed-planting machinery operated on the contour.

It is important to avoid excessive compacting of the soil surface when scarifying. Tracking with bulldozer treads is preferable to not roughening at all, but is not as effective as other forms of roughening, as the soil surface is severely compacted and runoff is increased.

Maintenance

Areas which are graded in this manner should be seeded as quickly as possible.

Regular inspections should be made. If rills appear, they should be regraded and reseeded immediately.

References

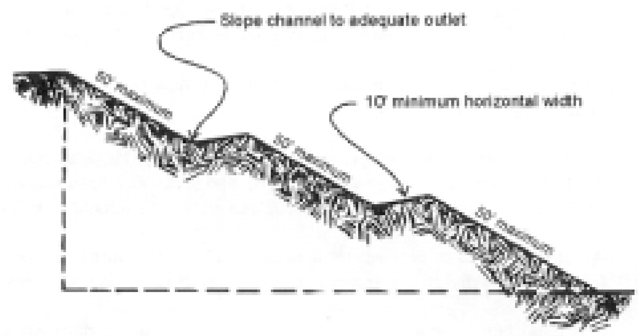
Massachusetts Department of Environmental Protection, Office of Watershed Management, Nonpoint Source Program, ***Massachusetts Nonpoint Source Management Manual, Boston***, Massachusetts, June, 1993.

U.S. Environmental Protection Agency, ***Storm Water Management For Construction Activities***, EPA-832-R- 92-005, Washington, DC, September, 1992.

Washington State Department of Ecology, ***Stotmwater Management Manual for the Puget Sound Basin***, Olympia, WA, February, 1992.

Terrace

A ridge and channel constructed across a slope and used to convey runoff water. Reduces erosion damage by intercepting surface runoff and conducting it to a stable outlet at a nonerosive velocity.



Where Practice Applies

Terraces are utilized on slopes having a water erosion problem. They should not be constructed on deep sands or on soils that are too stony, steep, or shallow to permit practical and economical installation and maintenance. Terraces should be used only where suitable outlets are or will be made available.

Advantages

Terraces lower the velocity of runoff, increase the distance of overland flow, and reduce slope length. They also hold moisture and minimize sediment.

Disadvantages/Problems

May significantly increase cut and fill costs and cause sloughing if excessive water infiltrates soils.

Design Recommendations

Spacing

The maximum recommended spacing is a maximum vertical distance of 20 feet between terraces or other practices such as a diversion, dike, or sediment fence at the top or bottom of a slope.

Channel Grade

Channel grades may be either uniform or variable with a maximum grade of 0.6 feet per 100 feet length. For short distances, terrace grades may be increased to improve alignment. The channel velocity should not exceed that which is nonerosive for the soil type with the planned treatment.

Outlet
All terraces should have adequate outlets. Such an outlet may be a grassed waterway, vegetated area, or subsurface drain outlet. In all cases the outlet must convey runoff from the terrace or terrace system to a point where the outflow will not cause damage. Vegetative cover should be used in the outlet channel.

The design elevation of the water surface of the terrace should not be lower than the design elevation of the water surface in the outlet at their junction, when both are operating at design flow.

Vertical spacing may be increased as much as 0.5 feet or 10 percent, whichever is greater, to provide better alignment or location, to avoid obstacles, to adjust for equipment size, or to reach a satisfactory outlet.

Capacity
The terrace should have enough capacity to handle the peak runoff expected from a 2-year, 24-hour design storm without overtopping.

Cross-Section
The terrace cross-section should be proportioned to fit the land slope. The ridge height should include a reasonable settlement factor and "freeboard" (vertical distance between top of ridge and water elevation in the channel at dewsign flow).

The minimum cross-sectional area of the terrace channel should be 8 square feet for land slopes of 5 percent or less, 7 square feet for slopes from 5 to 8 percent, and 6 square feet for slopes steeper than 8 percent. The terrace should be constructed wide enough to be maintained using a small bulldozer.

Maintenance

Maintenance should be performed as needed. Terraces should be inspected regularly; at least once a year, and after large storm events.

References

Minnick, E. L., and H. T. Marshall, ***Stormwater Management and Erosion Control for Urban and Developing Areas in New Hampshire***, Rockingham County Conservation District, August 1992.

Washington State Department of Ecology, ***Stormwater Management Manual for the Puget Sound Basin***, Olympia, WA, February, 1992.

Topsoiling

Preserving and using topsoil to provide a suitable growth medium and enhance final site stabilization with vegetation.

Where Practice Applies

- Where a sufficient supply of quality topsoil is available.
- Where slopes are 2:1 or flatter.
- Where the subsoil or areas of existing surface soil present the following problems:
  - The structure, pH, or nutrient balance of the available soil cannot be amended by reasonable means to provide an adequate growth medium for the desired vegetation.
  - The soil is too shallow to provide adequate rooting depth or will not supply necessary moisture and nutrients for growth of desired vegetation.
  - The soil contains substances toxic to the desired vegetation.
- Topsoiling is strongly recommended where ornamental plants or high-maintenance turf will be grown.

Advantages

Advantages of topsoil include higher organic matter and greater available water-holding capacity and nutrient content.

Topsoil stockpiling ensures that a good growth medium will be available for establishing plant cover on graded areas.

The stockpiles can be used as noise and view baffles during construction.

Disadvantages/Problems

Stripping, stockpiling, and reapplying topsoil, or importing topsoil may not always be cost-effective. It may also create an erosion problem if improperly secured.

Unless carefully located, storage banks of topsoil may also obstruct site operations and therefore require double handling.

Topsoiling can delay seeding or sodding operations, increasing exposure time of denuded areas.

Most topsoil contains some weed seeds.

Planning Considerations

Topsoiling may be required to establish vegetation on shallow soils, soils containing potentially toxic materials, very stony areas, and soils of critically low pH.

Topsoil is the surface layer of the soil profile, generally characterized as being darker than the subsoil due to the presence of organic matter. It is the major zone of root development and biological activities for plants, carrying much of the nutrients available to plants, and supplying a large share of the water used by plants. It should be stockpiled and used wherever practical for establishing permanent vegetation.

The need for topsoiling, should be evaluated. Take into account the amount and quantity of available topsoil and weigh this against the difficulty of preparing a good seedbed on the existing subsoil. Where a limited amount of topsoil is available, it should be reserved for use on the most critical areas. In many cases topsoil has already been eroded away or, as in wooded sites, it may be too trashy.

Make a field exploration of the site to determine if there is surface soil of sufficient quantity and quality to justify stripping. Topsoil should be spread at a depth of 2 to 4 inches. More topsoil will be needed if the subsoil is rocky.

Topsoil should be friable and loamy (loam, sandy loam, silt loam, sandy clay loam, clay loam). Areas of natural ground water recharge should be avoided.

Allow sufficient time in scheduling for topsoil to be spread and bonded prior to seeding, sodding, or planting.

Do not apply topsoil if the subsoil has a contrasting texture. Sandy topsoil over clayey subsoil is a particularly poor combination; water can creep along the junction between the soil layers and causes the topsoil to slough.

Stripping

Stripping should be confined to the immediate construction area. A 4 to 6 inch stripping depth is common, but depth may vary depending on the particular soil. All surface runoff control structures should be in place prior to stripping.

Stockpiling

Locate the topsoil stockpile so that it does not interfere with work on the site.

Side slopes of the stockpile should not exceed 2:1.

Surround all topsoil stockpiles with an interceptor dike with gravel outlet and silt fence.

Either seed or cover stockpiles with clear plastic or other mulching materials within 7 days of the formation of the stockpile.

Placement

Topsoil should not be placed while in a frozen or muddy condition, when the subgrade is excessively wet, or when conditions exist that may otherwise be detrimental to proper grading or proposed sodding or seeding.

Do not place topsoil on slopes steeper than 2:1, as it will tend to slip off.

If topsoil and subsoil are not properly bonded, water will not infiltrate the soil profile evenly and it will be difficult to establish vegetation. The best method is to actually work the topsoil into the layer below for a depth of at least 6 inches.

Maintenance

Maintain protective cover on stockpiles until needed.

References

Massachusetts Department of Environmental Protection, Office of Watershed Management, Nonpoint Source Program, ***Massachusetts Nonpoint Source Management Manual,*** Boston, Massachusetts, June, 1993.

Washington State Department of Ecology, ***Stormwater Management Manual for the Puget Sound Basin***, Olympia, WA, February, 1992.

Tree and Shrub Planting

Stabilizing disturbed areas by establishing a vegetative cover of trees or shrubs.

Purpose

- To stabilize the soil with vegetation other than grasses or legumes.
- To provide food and shelter for wildlife.
- To provide windbreaks or screens.

Where Practice Applies

Trees and shrubs may be used:

- On steep or rocky slopes,
- Where mowing is not feasible,
- As ornamentals for landscaping purposes, or
- In shaded areas where grass establishment is difficult.

Advantages

Trees and shrubs can provide superior, low-maintenance, long-term erosion protection. They may be particularly useful where site aesthetics are important.

Besides their erosion and sediment control values, trees and shrubs also provide natural beauty and wildlife benefits.

Disadvantages/Problems

Except for quick-growing species; it may take a number of years for trees to reach full size.

Trees and shrubs may be expensive to purchase and establish. They may also be more subject to theft than materials used in other practices.

Planning Considerations

There are many different species of plants from which to choose, but care must be taken in their selection. It is essential to select planting material suited to both the intended use and specific site characteristics.

None of these plants, however, is capable of providing the rapid cover possible by using grass and legumes. Vegetative plans must include close-growing plants or an adequate mulch with all plantings.

When used for natural beauty and wildlife benefits, trees and shrubs are usually more effective when planted in clumps or blocks.

Species Selection

When erosion or sediment control is not of primary, immediate concern; areas may be stabilized using rugged, fast-growing trees and shrubs that once established have a good record of taking care of themselves. These plants may not be the best ornamentals, but establishment can usually be made with these low-maintenance trees and shrubs.

In some cases, it may be desirable to use trees and shrubs as screening plants to shield sites such as gravel pits from public view. These plants should be given the best possible attention at planting time, with good soil water, and mulching.

Shrub and tree species recommendations for various soil conditions, densities, and arrangements will be found in Part 4 of this document.

Planting

Trees and shrubs will do best in topsoil. If no topsoil is available, they can be established in subsoil with proper amendment. If trees and shrubs are to be planted in subsoil, particular attention should be paid to amending the soil with generous amounts of organic matter. Mulches should also be used.

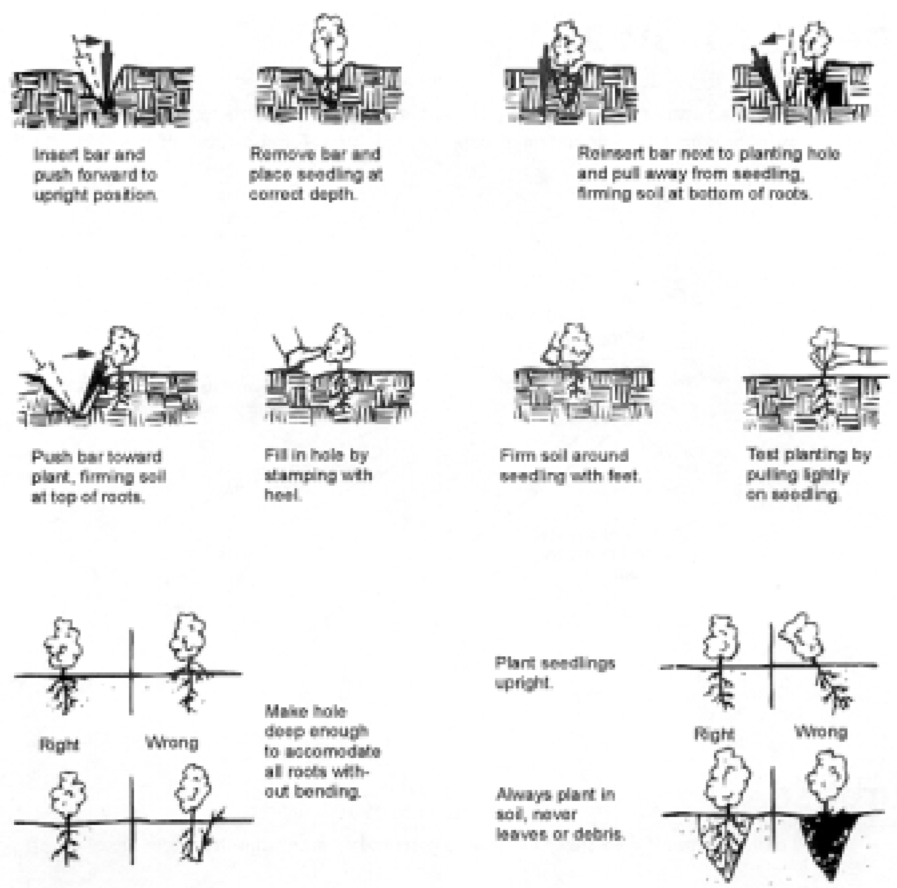
Good quality planting stock should be used. For mass plantings one or two-year old deciduous seedlings, and 3 or 4-year old coniferous transplants should be used. For smaller planting groups or individuals specimen plants, bare rooted, container grown or balled and burlaped stock may be preferred because of their larger size. Stock should be kept cool and moist from time of receipt until planted.

Competing vegetation, if significant, should be destroyed or suppressed prior to planting by scalping a small area where the plant is to be placed.

Stock should be planted in the spring by May 15. No fertilizer should be used at the time of planting unless it is a slow-release type formulated for trees and shrubs.

Plants should be planted at the approximate depth they were growing in the nursery; the roots should be uncrowded; the soil should be firmly packed against the roots after setting.

Shrubs should be mulched to a depth of 4 inches or more with woodchips, bark, peat moss or crushed stone. Mulch to the edge of the planting at, but not less than, one foot from the trunk.



Maintenance

Deciduous plants should be fertilized six months to one year after planting with ¼ pound of a 10-6-8 fertilizer per plant (or 25 lbs. per 1,000 sq. ft. for block plantings) or the equivalent. A slow release fertilizer is preferred. Evergreens should be fertilized half as much.

The planting should be inspected after the first and second growing seasons. Replanting and repairs, as needed to provide adequate cover, should be scheduled. Fertilizer should be applied to shrubs every 3 to 5 years after planting.

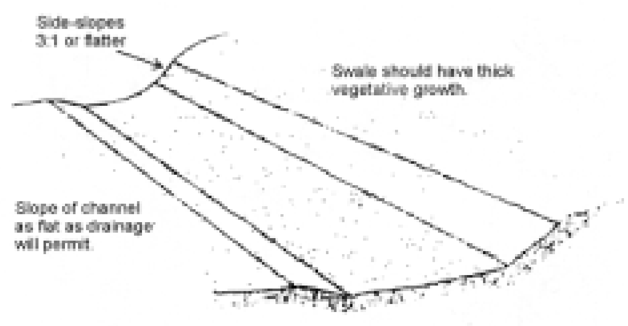
References

Massachusetts Department of Environmental Protection, Office of Watershed Management, Nonpoint Source Program, ***Massachusetts Nonpoint Source Management Manual,*** Boston, Massachusetts, June, 1993.

Vegetated Swale

Vegetated swales are broad channels, either natural or constructed, with dense vegetation; whose purpose is to retard or impound concentrated runoff and dispose of it safely into the drainage system.

Purpose



To reduce runoff velocities, and reduce potential erosion from the discharge of runoff.

Vegetated swales may also remove some particulate pollutants from stormwater runoff and increase infiltration.

Where Practice Applies

This practice applies to all sites where a dense stand of vegetation can be established and where either a stable outlet exists or can be constructed as a suitable conveyance system to safely dispose of the runoff flowing from the swale.

The swale can be used by itself or in combination with erosion and sediment control practices:

- In residential areas of low to moderate density where the percentage of impervious cover is relatively small.
- In a drainage easement at the side or back of residential lots.
- Adjacent to parking areas.
- Along highway medians as an alternative to curb and gutter drainage systems.

Planning Considerations

The vegetated swale and the grassed waterway are very similar. The difference in the two practices is mainly in purpose. The vegetated swale is used for water quality improvement and peak runoff reduction; accomplished by limiting the velocity in the swale. The grassed waterway or outlet is used to convey runoff at a non-erosive velocity.

Vegetated swales are best suited on small drainage areas where the amount of impervious cover is relatively small. If dense vegetation cannot be established and maintained in the swale, then its effectiveness is severely reduced.

The seasonal high water table should be at least two feet below the bottom of the swale in order to provide for more effective infiltration and treatment of the runoff and to provide better growing conditions for the vegetation. Subsurface drainage may be needed to control high water table and improve the condition of the swale.

The swale should be constructed prior to any other channel or facility which will drain into it and flow should be diverted out of the swale until adequate vegetation is established.

Vegetated swales should generally not receive construction-stage runoff; if they do, presettling of sediments should be provided.

Swales should be protected from siltation by a sediment pond or basin when the erosion potential is high; otherwise, presettling is not generally needed for normal operation.

Soil moisture should be sufficient to provide water requirements during the dry season, but where the water table is not so high as to cause long periods of soil saturation. Irrigate if moisture is inadequate during summer drought. If saturation will be extended or the slope is minimal but grasses are still desired, consider subdrains.

Prevent bare areas by avoiding gravel, rocks, and hardpan near the surface.

Design Recommendations

The minimum capacity should be that required to convey the peak runoff expected from a 10-year frequency 24-hour duration storm.

The maximum design velocity for a vegetated swale should be one foot per second during passage of the 10-year frequency storm.

The minimum recommended length of a vegetated swale is 200 feet. If a shorter length must be used, increase swale cross-sectional area by an amount proportional to the reduction in length below 200 feet, in order to obtain the same water residence time.

The channel slope should normally be between 2 and 4 percent. A slope of less than 2 percent can be used if underdrains are placed beneath the channel to prevent ponding. A slope of greater than 4 percent can be used if check dams are placed in the channel to slow the flows accordingly.

Install log or rock check dams approximately every 50 feet, if longitudinal slope exceeds 4 percent. Adjust check dam spacing in order not to exceed 4 percent slope within each channel segment between dams.

The cross section for a vegetated swale may be parabolic, triangular, or trapezoidal.

If flow is introduced to the swale via curb cuts, place pavement slightly above the swale elevation. Curb cuts should be at least 12 inches wide to prevent clogging.

Subsurface drainage measures should be provided if sites have high water tables or seepage problems, except where water-tolerant vegetation such as reed canary grass can be used. There should be no base flow present in the swale.

Vegetative Recommendations

Swales should be vegetated with an appropriate grass mixture: The swale should be mulched if necessary for establishment of good quality vegetation. A temporary diversion should be used to divert runoff away from the swale until vegetation is established that is capable of preventing erosion.

Select vegetation according to what will best establish and survive in the site conditions. Select fine, close-growing, water-resistant grasses. If a period of soil saturation is expected, select emergent wetland plant species. Protect these plants during establishment by netting.

Select a grass height of 6 inches or less and a flow depth of less than 5 inches. Grasses over that height tend to flatten down when water is flowing over them, which prevents sedimentation.

Construction Recommendations

Avoid compaction during construction. If compaction occurs, till before planting to restore lost soil infiltration capacity.

Divert runoff during the period of vegetation establishment. Sodding is an alternative for rapid stabilization. Where it is not possible to divert runoff, cover graded and seeded areas with a suitable erosion control slope covering material.

Maintenance

Timely maintenance is important to keep the vegetation in the swale in good condition. Mowing should be done frequently enough to keep the vegetation in vigorous condition and to control encroachment of weeds and woody vegetation, however it should not be mowed too closely so as to reduce the filtering effect.

Fertilize on an “as needed” basis to keep the grass healthy. Over-fertilization can result in the swale becoming a source of pollution.

The swale should be inspected periodically and after every major storm to determine the condition of the swale. Rills and damaged areas should be promptly repaired and re-vegetated as necessary to prevent further deterioration.

Vegetated swales planted in grasses must be mowed regularly during the summer to promote growth and pollutant uptake. Plan on mowing as needed to maintain proper height. Remove cuttings promptly, and dispose in a way so that no pollutants can enter receiving waters.

Remove sediments during summer months when they build up to 6 inches at any spot or cover vegetation. If the equipment leaves bare spots, re-seed them immediately.

Inspect periodically, especially after periods of heavy runoff. Remove sediments, fertilize, and reseed as necessary. Be careful to avoid introducing fertilizer to receiving waters or ground water.

Clean curb cuts when soil and vegetation buildup interferes with flow introduction.

References

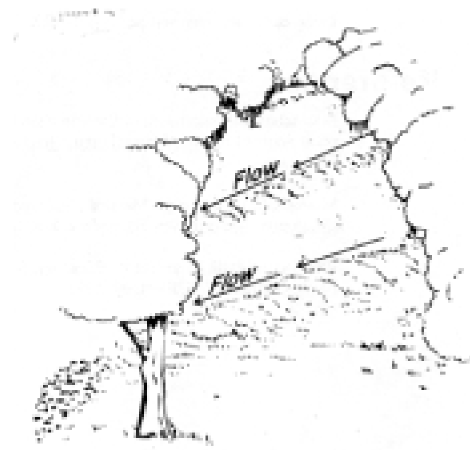
Massachusetts Department of Environmental Protection, Office of Watershed Management, Nonpoint Source Program, ***Massachusetts Nonpoint Source Management Manual,*** Boston, Massachusetts, June, 1993.

Minnick, E. L., and H. T. Marshall, ***Stormwater Management and Erosion Control for Urban and Developing Areas in New Hampshire***, Rockingham County Conservation District, August 1992.

Washington State Department of Ecology, ***Stormwater Management Manual for the Puget Sound Basin***, Olympia, WA, February, 1992.

Water Bar

A ridge or ridge and channel constructed diagonally across a sloping road or utility right-of-way that is subject to erosion. Used to prevent erosion on long, sloping right-of-way routes by diverting runoff at selected intervals.



Where Practice Applies

- Where runoff protection is needed to prevent erosion on sloping access right-of-ways.
- On sloping areas generally less than 100 feet in width.

Disadvantages/Problems

Need maintenance periodically for vehicle wear.

Planning Considerations

Narrow rights-of-way on long slopes used by vehicles can be subject to severe erosion. Surface disturbance and tire compaction promote gully formation by increasing the concentration and velocity of runoff.

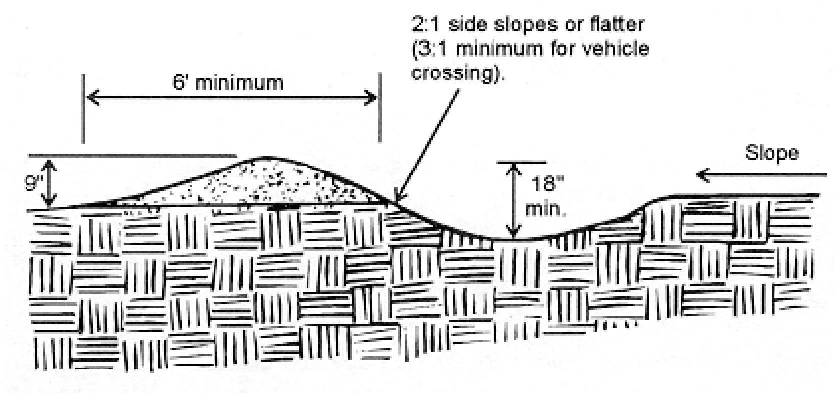
Water bars are constructed by forming a ridge or ridge and channel diagonally across the sloping right-of-way. Each outlet should be stable, and should be able to handle the cumulative effect of upslope diversion outlets. The height and side slopes of the ridge and channel are designed to divert water and to allow vehicles to cross.

Design Recommendations

Height - 18 inches minimum from channel bottom to top of settled ridge.
Side slopes - 2:1 or flatter (3:1 or flatter where vehicles cross).
Spacing - For right-of-way widths less than 100 feet; spacing as follows:

Slope (%)	Diversion Spacing (feet)
< 5	125
5 to 10	100
10 to 20	75
20 to 35	50
>35	25

Base width of ridge - 6 feet minimum.
Grade - Constant or slightly increasing, not to exceed 2%.
Outlet - Diversion must cross the full access width and extend to a stable outlet.



Installation

Construct the diversion system as soon as the access right-of-way has been cleared and graded. Locate first diversion at required distance from the slope crest depending on steepness of right-of-way slope. Set crossing angle to keep positive grade less than 2% (approximately 60-degree angle preferred).

Mark location and width of ridge and disk the entire length.

Fill and compact ridge above design height and compact with wheeled equipment to the design cross section.

Construct diversions on constant or slightly increasing grade not to exceed 2%. Avoid reverse grades.

Set direction of water bars to utilize the most stable outlet locations. If necessary, adjust length of waterbars or make small adjustments to spacing.

Do not allow runoff from upslope water bars to converge with downslope water bar outlets.

Construct sediment traps or outlet stabilization structures as needed.

Seed and mulch the ridge and channel immediately.

Common Trouble Points

Overtopping ridge where diversion crosses low areas - Build water bars to grade at all points.

Erosion between water bars - Spacing too wide for slope. Install additional water bars.

Ridge worn down - Channel filled where vehicles cross; surface not stable; or side slopes too steep: may need gravel.

Erosion at outlets - Install outlet stabilization structure or extend upslope water bar so runoff will not converge on lower outlets.

Erosion in channel - Grade too steep. Realign water bar.

Maintenance

Inspect water bars periodically for vehicle wear. Inspect for erosion and sediment deposition after heavy rains.

Remove debris and sediment from diversion channel and sediment traps, repair ridge to positive grade and cross section. Add gravel at crossing areas and stabilize outlets as needed.

Repair and stabilize water bars immediately if right-of-way is disturbed by installation of additional utilities.

In removing temporary water bars, grade ridge and channel to blend with natural ground. Compact channel fill and stabilize disturbed areas with vegetation. Water bars should not be removed until all disturbed areas draining to them have been stabilized, inspected, and approved.

If water bars are designed for permanent use, correct any erosion problems, stabilize outlets, and apply permanent seeding.

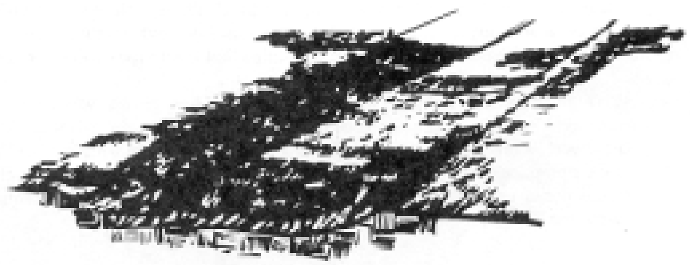
References

Massachusetts Department of Environmental Protection, Office of Watershed Management, Nonpoint Source Program, ***Massachusetts Nonpoint Source Management Manual***, Boston, Massachusetts, June, 1993.

North Carolina Department of Environment, Health, and Natural Resources, ***Erosion and Sediment Control Field Manual***, Raleigh, NC, February 1991.

Waterway, Grassed

A natural or constructed waterway or outlet shaped or graded and established in suitable vegetation as needed for the safe disposal of runoff water. Used to convey and dispose of concentrated runoff to a stable outlet without damage from erosion, deposition, or flooding.



Where Practice Applies

This practice applies to construction sites where:

- Concentrated runoff will cause damage from erosion or flooding,
- A vegetated lining can provide sufficient stability for the channel cross section and grade,
- Slopes are generally less than 5 percent, and
- Space is available for a relatively large cross section.

Typical uses include roadside ditches, channels at property boundaries, and outlets for diversions.

Planning Considerations

Grass-lined channels resemble natural systems and are usually preferred where design velocities are suitable. Select appropriate vegetation and construct channels early in the construction schedule before grading and paving increase runoff rates.

Two major considerations for a grassed waterway are adequate capacity and sufficient erosion resistance.

The channel cross section should be wide and shallow with relatively flat side slopes so surface water can enter over the vegetated banks without causing erosion.

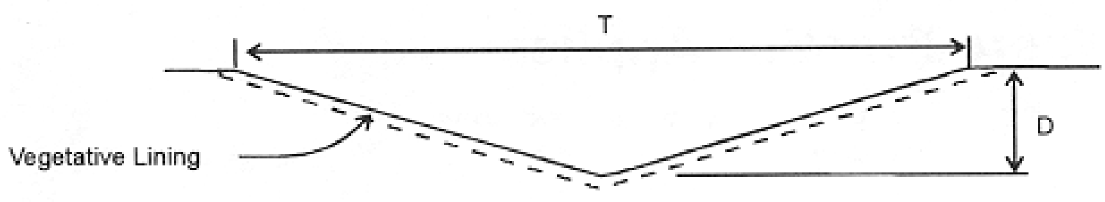
Vegetation should be established before runoff is allowed to flow in the waterway.

Supplemental measures may be needed with this practice. These may include but not be limited to such things as:

- Grade control structures,
- Level spreaders,
- Paved or rock-lined bottom, or
- Subsurface drain to eliminate wet spots and permit growing suitable vegetation.

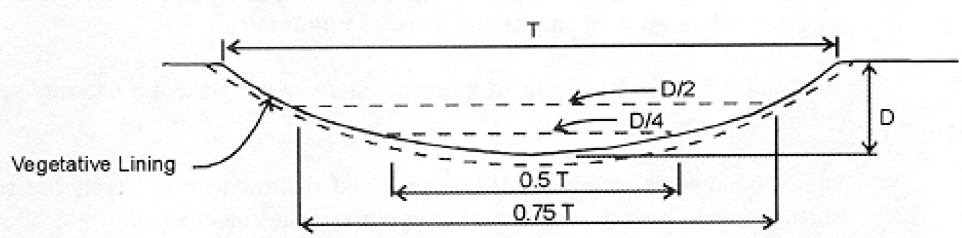
Primary considerations for a stormwater conveyance channel are the volume, velocity, and duration of flow expected in the channel. In addition, there are several other factors that should be taken into consideration when planning a channel. These include soil characteristics, safety, aesthetics, availability of land, compatibility with land use and surrounding environment, and maintenance requirements. The type of cross section that is selected depends on these factors.

Triangular sections are used where the volume of flow is relatively small, such as in roadside ditches. Vegetation can be used in these ditches where the velocities are low. On steep slopes, however, where higher velocities are encountered; it may be necessary to line the channel with rock riprap, concrete, asphalt or other erosion resistant lining. Triangular cross-sections may be more prone to erosion because during small flows, the flow is concentrated in the narrow v-section.



Triangular Cross-section

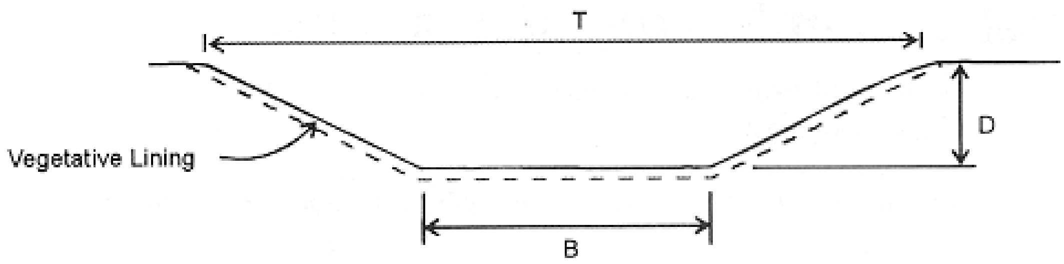
Parabolic sections are suited for higher flows, but require the use of more land because the channels are generally shallow and wide. These channels seem to blend better in natural settings when grass mixtures are used as a lining. When velocities exceed the capability of vegetation, rock riprap can be used as a lining. When there is a continuous base flow in the channel it may be possible to use a combination of rock riprap and vegetation as a lining. The base flow would be carried by the riprap section and the higher flows by the vegetated section as long as the vegetation is capable of withstanding the velocity.



Parabolic Cross-section

A trapezoidal channel is usually used where the flows are relatively large and at higher velocities. These channels are usually lined with materials other than vegetation. Trapezoidal channels usually take up less land than either triangular or parabolic channels.

Regardless of the channel shaped selected, the outlet should be checked to determine if it is stable. It may be necessary to have some type of energy dissipater to prevent scour to the receiving outlet if there is an overflow or if velocities in the contributing channel are higher than the outlet can withstand.



Trapezoidal Cross-section

Design Recommendations

Capacity - The minimum capacity should be that required to convey the peak runoff expected from a storm of 10-year frequency. Peak runoff values should be determined by accepted methods.
To provide for loss in channel capacity due to vegetal matter accumulation, sedimentation, and normal seedbed preparation, the channel depth and width may be increased proportionally to maintain the hydraulic properties of the waterway. In parabolic channels, this may be accomplished by adding 0.3 foot to the depth and 2 feet to the top width of the channel. This is not required on waterways located in natural watercourses.

Cross Section - The cross section may be parabolic, triangular, or trapezoidal.

Grade - Generally restricted to slopes 5% or less.

Sideslopes - Generally 3:1 or flatter to establish and maintain vegetation and facilitate mowing.
Where a paved or stone-lined bottom is used in combination with vegetated side slopes, it should be designed to handle the base flow, snowmelt, or runoff from a one-year frequency storm, whichever is greater. The flow depth of the paved section should be a minimum of 0.5 feet.

Width - The bottom width of waterways or outlets should not exceed 50 feet unless multiple or divided waterways or other means are provided to control meandering of low flows within this limit.

Drainage - Subsurface drainage measures should be provided in the design for sites having high water table or seepage problems, except where water-tolerant vegetation such as reed canarygrass can be used. Where there is base flow present or long duration flows are expected, a stone center or underground outlet should be used.

Outlet - The outlet must be stable. Channels carrying sediment must empty into sediment traps.

Stabilization - Waterways should be stabilized with vegetative measures or stone centers. If a vegetated lining is supplemented by stone center, or other erosion-resistant materials, the velocity may be increased by 2.0 ft/sec.

Construction Recommendations

Remove all trees, brush, stumps, and other objectionable material from the foundation area and dispose of properly.

Install traps or other measures to protect grassed waterways from sediment.

The channel section should be free of bank projections or other irregularities which prevent normal flow.

Excavate and shape channel to dimensions shown on plans. Overcut entire channel 0.2 ft to allow for bulking during seedbed preparation and growth of vegetation. If installing sod, overcut channel the full thickness of the sod.

Remove and properly dispose of excess soil so that surface water may enter the channel freely.

Earth removed and not needed in construction should be spread or disposed of so as not to interfere with the functioning of the waterway.

Fills placed in waterways should be thoroughly compacted in order to prevent unequal settlement that could cause damage in the completed waterway.

Protect all concentrated inflow points along channel by installing a temporary liner, riprap, sod, or other appropriate measures.

Stabilize outlets and install sediment traps as needed during channel installation.

Vegetate the channel immediately after grading. Smooth slopes facilitate maintenance.

Establishing Vegetation

Waterways should be protected by vegetative means as soon after construction as practical, and before diversions or other channels are outletted into them. Consideration should be given to jute matting, excelsior matting, or sodding of channel to provide erosion protection as soon after construction as possible.

Install sod instead of seeding in critical areas, particularly where slopes approach 5%.

Seeding, fertilizing, mulching, and sodding should be in accord with applicable vegetative standards for permanent cover. See Permanent Seeding.

One-half to one bushel of oats should be added to the basic mixture for quick cover and to help anchor the mulch.

Very moist waterways are often best vegetated by working rootstocks of reed canarygrass into the seedbed.

When soil conditions are unfavorable for vegetation (such as very coarse-textured subsoil material), topsoil should be spread to a depth of 4 inches or more on at least the center half of parabolic shaped channels or on the entire bottom of trapezoidal shaped channels.

Seeded channels should be mulched. For critical sections of large channels, and for steep channels, the mulch should be anchored by cutting it lightly into the soil surface, or by covering with paper twine fabric or equivalent material; or jute netting should be used.

Common Trouble Points

Erosion occurs in channel before vegetation is fully established
Repair, reseed, and install temporary liner.

Gullying or head cutting in channel
Grade too steep for grass lining (steep grade produces excessive velocity). Channel and liner should be redesigned.

Sideslope caving
May result from any of the following:

- channel dug in unstable soil (high water table),
- banks too steep for site conditions, or
- velocity too high, especially on outside of channel curves.

Overbank erosion, spot erosion, channel meander, or flooding
Avoid debris and sediment accumulation. Stabilize trouble spots and revegetate. Riprap or other appropriate measures may be required.

Ponding along channel
Approach not properly graded, surface inlets blocked.

Erosion at channel outlet
Install outlet stabilization structure.

Sediment deposited at channel outlet
Indicates erosion in channel or watershed. Find and repair any channel erosion. Stabilize watershed, or install temporary diversions and sediment traps to protect channel from sediment-laden runoff.

Maintenance

During the initial establishment period, flow should be diverted out of the channel if at all possible to allow for a good stand of grass. If this is not possible use matting. In any case during the establishment period, the channel should be checked after every rainfall to determine if the grass is still in good condition and in place.

After the vegetation has become established, the channel should be checked periodically and after every major storm to see if damage has occurred. Any damaged areas should be repaired and revegetated immediately.

Maintenance of the vegetation in the grassed waterway is extremely important in order to prevent rilling, erosion, and failure of the waterway.

Mowing should be done frequently enough to control encroachment of weeds and woody vegetation and to keep the grasses in a vigorous condition. The vegetation should not be mowed too closely so as to reduce the erosion resistance in the waterway.

Periodic applications of lime and fertilizer may be needed to maintain vigorous growth.

Remove all significant sediment and debris from channel to maintain the design cross section and grade and prevent spot erosion.

Existing waterways can often be best repaired by working sods of witchgrass (quackgrass) into the seedbed.

It is important to check the channel outlet and all road crossings for blockage, sediment, bank instability, and evidence of piping or scour holes.

References

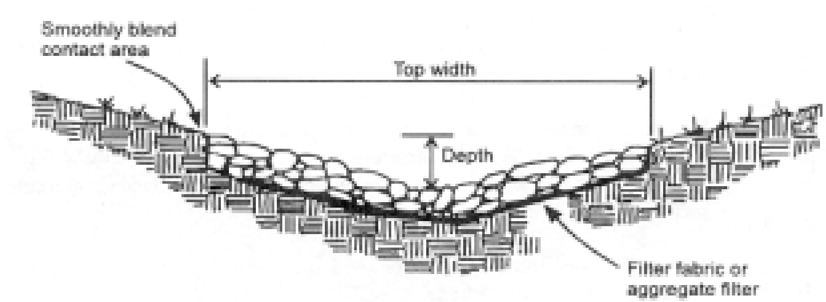
Massachusetts Department of Environmental Protection, Office of Watershed Management, Nonpoint Source Program, ***Massachusetts Nonpoint Source Management Manual***, Boston, Massachusetts, June, 1993.

Minnick, E. L., and H. T. Marshall, S***tormwater Management and Erosion Control for Urban and Developing Areas in New Hampshire***, Rockingham County Conservation District, August 1992.

North Carolina Department of Environment, Health, and Natural Resources, ***Erosion and Sediment Control Field Manual***, Raleigh, NC, February 1991.

Waterway, Lined

A waterway with an erosion resistant lining of concrete, stone, or other permanent material. The lined section extends up the side slopes to design flow depth. The earth above the permanent lining should be vegetated or otherwise protected.



Purpose

To provide for safe disposal of runoff from other conservation structures or from natural concentrations of flow, without damage by erosion or flooding, where unlined or grassed waterways would be inadequate.

Where Practice Applies

This practice applies where channel flow velocities exceed those acceptable for a grass lined waterway and/or conditions are unsuitable for the establishment of grass lined waterways. Specific conditions include:

- Concentrated runoff is of such magnitude that a lining is needed to control erosion.
- Steep grades, wetness, prolonged or continuous base flow, seepage, or piping would cause erosion.
- The location is such that use by people, animals, or vehicles preclude use of vegetated waterways.
- High value property or adjacent facilities warrant the extra cost to contain design runoff in limited space.
- Soils are highly erosive or other soil or climate conditions preclude using vegetation.

Planning Considerations

Linings can consist of: rock riprap; non-reinforced, cast-in-place concrete, flagstone mortared in place; or similar permanent linings.

Riprap liners are considered flexible and are usually preferred to rigid liners.

Riprap is less costly, adjusts to unstable foundation conditions, is less expensive to repair, and reduces outlet flow velocity.

Riprap or paved channels can be constructed with grass lined slopes where site conditions warrant.

Volume, velocity, and duration of flow expected are primary considerations for a lined waterway. Other factors include soil characteristics, safety, aesthetics, availability of land, compatibility with land use and surrounding environment, and maintenance requirements. The type of cross section that is selected depends on these factors.

Typical cross sections that can be used include triangular or v-shaped sections, parabolic sections, and trapezoidal sections.

- Triangular sections are used where the volume of flow is relatively small, such as in roadside ditches.
- Parabolic sections are suited for higher flows, but require the use of more land because the channels are generally shallow and wide. When velocities exceed the capability of vegetation, rock riprap can be used as a lining. When there is a continuous base flow in the channel it may be possible to use a combination of rock riprap and vegetation as a lining. The base flow would be carried by the riprap section and the higher flows by the vegetated section; as long as the vegetation is capable of withstanding the velocity.
- A trapezoidal channel is usually used where the flows are relatively large and at higher velocities. Trapezoidal channels usually take up less land than either triangular or parabolic channels.

Regardless of the channel shaped selected, the outlet should be checked to determine if it is stable. It may be necessary to have some type of energy dissipater to prevent scour to the receiving outlet if there is an overflow or if velocities in the contributing channel are higher than the outlet can withstand.

The Wetlands Protection Act requires that for any stream crossing or other work conducted in a wetland resource area, or within 100 feet of a wetland resource area, the proponent file a “Determination of Applicability” or a “Notice of Intent” with the local Conservation Commission.

Design Recommendations

See also **Riprap**.

Capacity - The minimum capacity should be adequate to carry the peak rate of runoff from a 10-year frequency storm.

Cross Section - The cross section may be triangular, parabolic, or trapezoidal. Monolithic concrete may be rectangular.

Velocity

Rock Riprap Lined Waterways - Rock riprap linings can be designed to withstand high velocities by choosing a stable rock size. Riprap should have a transition material (bedding) placed between the rock and the soil. This transition material can be either a well graded sand-gravel mixture or a geotextile fabric.

Concrete-Lined Waterways - Velocity is usually not a limiting factor in the design of concrete-lined waterways. Keep in mind however that the flow velocity at the outlet must not exceed the allowable velocity for the receiving outlet.

Drainage - Drainage is not a factor when considering using a rock riprap waterway since subsurface water will drain through the transition material and the rock. Concrete lined channels may require drainage to reduce uplift pressure and collect seepage water.

Filters or bedding - Filters or bedding should be used to prevent piping. Filter fabric may be used as the filter. Drains should be used, as required, to reduce uplift pressure and collect water. Weep holes may be used with drains if needed.

Rock Riprap or Flagstone - Stone used for riprap or flagstone should be dense and hard enough to withstand exposure to air, water, freezing and thawing. Flagstone should be flat for ease of placement, and have the strength to resist exposure and breaking.

Construction Recommendations

Outlet must be stable. Stabilize channel inlet points and install needed outlet protection during channel installation.

Remove all trees, brush, stumps, and other objectionable material from channel and spoil areas and dispose of properly.

Construct cross section to the lines and grades shown in plans. Install filter fabric or gravel layer as specified in the plan.

Common Trouble Points

Foundation not excavated deep enough or wide enough
Riprap restricts channel flow, resulting in overflow and erosion.

Side slopes too steep
Causes instability, stone movement and bank failure.

Filter omitted or damaged during stone placement
Causes piping and bank instability.

Riprap poorly graded or stones not placed to form a dense, stable channel lining
Results in stone displacement and erosion of foundation.

Riprap not extended far enough downstream
Causes undercutting. Outlet must be stable.

Riprap not blended to ground surface
Results in gullying along edge of riprap.

Maintenance

Check riprap-lined waterways periodically and after every major storm for scouring below the riprap layer, and to see that the stones have not been dislodged by the flow. Plastic filter cloth, if used, should be completely covered and protected from sunlight.

If the rocks have been displaced or undermined, the damaged areas should be repaired immediately. Woody vegetation should not be allowed to become established in the rock riprap and if present should be removed. Debris should not be allowed to accumulate in the channel.

Give special attention to outlets and points where concentrated flow enters channel. Repair eroded areas promptly.

Concrete-lined waterways should be checked to ensure that there is no undermining of the channel. If scour is occurring at the outlet, appropriate energy dissipation measures should be taken.

If the waterway is below a high sediment-producing area, sediment should be trapped before it enters.

Check for sediment accumulation, piping, bank instability, and scour holes. Sediment and debris deposits should be removed before they reduce the capacity of the channel.

References

Connecticut Council on Soil and Water Conservation, ***Connecticut Guidelines for Soil Erosion and Sediment Control***, Hartford, CT, January, 1985.

Massachusetts Department of Environmental Protection, Office of Watershed Management, Nonpoint Source Program, ***Massachusetts Nonpoint Source Management Manual***, Boston, Massachusetts, June, 1993.

Minnick, E. L., and H. T. Marshall, ***Stormwater Management and Erosion Control for Urban and Developing Areas in New Hampshire***, Rockingham County Conservation District, August 1992.

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